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BALLISTIC MISSILE DEFENSE ORGANIZATION 1998 TECHNOLOGY APPLICATIONS REPORT

BALLISTIC MISSILE DEFENSE ORGANIZATION 1998 TECHNOLOGY APPLICATIONS REPORT



To defend against ballistic missile attacks, the Ballistic Missile Defense Organization (BMDO) is developing some of the world's most advanced technology. Super-sensitive heat detectors, highly precise optical components, and speedy optical data routers—these are just a few of the many cutting-edge devices being created for ballistic missile defense. And the same technology BMDO is developing provides U.S. taxpayers with a wide range of new commercial products, including more sophisticated cancer detectors, higher-quality wireless communications equipment, and more reliable automobile air bag systems. It also boosts the U.S. economy by creating new jobs and new businesses to commercialize these products.

For over a decade, BMDO's Technology Applications program has assisted small and large companies, universities, and Federal laboratories in commercializing BMDO-funded technologies. It looks at hundreds of these leading-edge technologies and invites and encourages U.S. industry to use them in the commercial marketplace. As part of its mission, the program undertakes several innovative and proactive approaches to assist companies in transferring their BMDO-funded technologies to the commercial marketplace.

The first part of this report describes these approaches and how they benefit U.S. companies conducting BMDO-funded research and development. The second part of the report highlights 24 BMDO-funded technologies that have been or are being commercialized in areas such as communications, energy, health, manufacturing, and materials. In each example, readers are told how the technology benefits U.S. taxpayers and our Nation.

For more information about technologies and organizations featured in this report, please contact:

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Continuing the Legacy of American Innovation

The spirit of innovation and commercialization has long existed in the bedrock of our Nation's technical community. We can think of two early pioneers, Thomas Edison and George Westinghouse, Jr., who captured this spirit and made a significant impact on the American economy and its people.

Edison, who earned patents for more than 1,000 inventions, including the incandescent lamp, the phonograph, the carbon telephone transmitter, and the motion-picture projector, collaborated with a group of investors to form the Edison Electric Light Company, the predecessor of today's General Electric (GE) Company. Westinghouse invented a system of air brakes that made travel by train safer and later founded Westinghouse Electric Company which, coincidentally, became a competitor to GE.

Over the years, these two companies maintained the vision and entrepreneurial enthusiasm of their founders by expanding their businesses around new products and processes. A measure of their innovation success comes from the U.S. Patent and Trademark Office, which reports that from 1963 to 1984 GE received more U.S. patents than any other American company; Westinghouse was ranked fifth on the list, behind AT&T, IBM, and the U.S. Navy.¹

The Ballistic Missile Defense Organization (BMDO) plays a major role in continuing the legacy of American innovation. It funds not only large companies such as GE and Westinghouse, but also small companies led by individuals with a spirit of innovation and commercialization much like that exhibited by Edison and Westinghouse. As you read through this report, keep in mind that BMDO has an enduring commitment to innovative technology development, together with a strong emphasis on the transfer and commercialization of this technology.

¹In 1995, Westinghouse acquired CBS Corporation; in 1998, however, Morrison Knudsen Corporation and BNFL formed a joint venture to acquire Westinghouse from CBS.

BALLISTIC MISSILE DEFENSE ORGANIZATION
1998 TECHNOLOGY APPLICATIONS REPORT



Ballistic Missile Defense Organization

FOREWORD

The Ballistic Missile Defense Organization (BMDO) is committed to the development of innovative technologies that strengthen our Nation's defense. In the same spirit of commitment, BMDO is dedicated to technology transfer and commercialization: moving state-of-the-art military technology into the commercial sector. In a rapidly changing world, maintaining technological superiority is key not only to a secure Nation but also to economic stability, job creation, and industry growth. Thus, there are additional benefits to BMDO's investment in technical progress. BMDO technologies are finding their way into products and services benefiting many aspects of our economy—medicine, manufacturing, communications, and transportation, to name just a few. For example

■ ***BMDO's development of high-energy capacitors originally addressed the military need for compact, lightweight power sources for space-based lasers and accelerators.*** These same capacitors are being used to kill deadly bacteria, viruses, and other microorganisms, allowing restaurants to serve safer drinking water, hot and cold beverages, and ice cubes.

■ ***BMDO's interest in satellite threat assessment led to research in structural health monitoring systems.*** A simple, low-cost sensor that reliably detects and measures ice formation on aircraft airfoils during flight resulted from these efforts. Soon, this sensor may be flying on several commercial jets, helping pilots avoid the danger of icing.

■ ***BMDO's research in adaptive phased-array radar helped create devices to locate airborne vehicles, such as cruise missiles, from BMDO space-based radar platforms.*** This technology is now helping doctors to produce safe, controlled, deep microwave radiation to treat patients with breast cancer and other life-threatening diseases.

Many other examples of successful technology transfer and commercialization are contained in the *1998 Technology Applications Report*. We invite you to read about them and hope the stories they tell will encourage you to ask for more information.



Dr. Dwight Duston
Assistant Deputy
BMDO Technical Operations

Note: Dr. Duston left his position of Assistant Deputy of BMDO Technical Operations and as program manager for the technology transfer program at the end of 1998. We will sorely miss his leadership, capability, assistance, and abiding interest in BMDO technology transfer.

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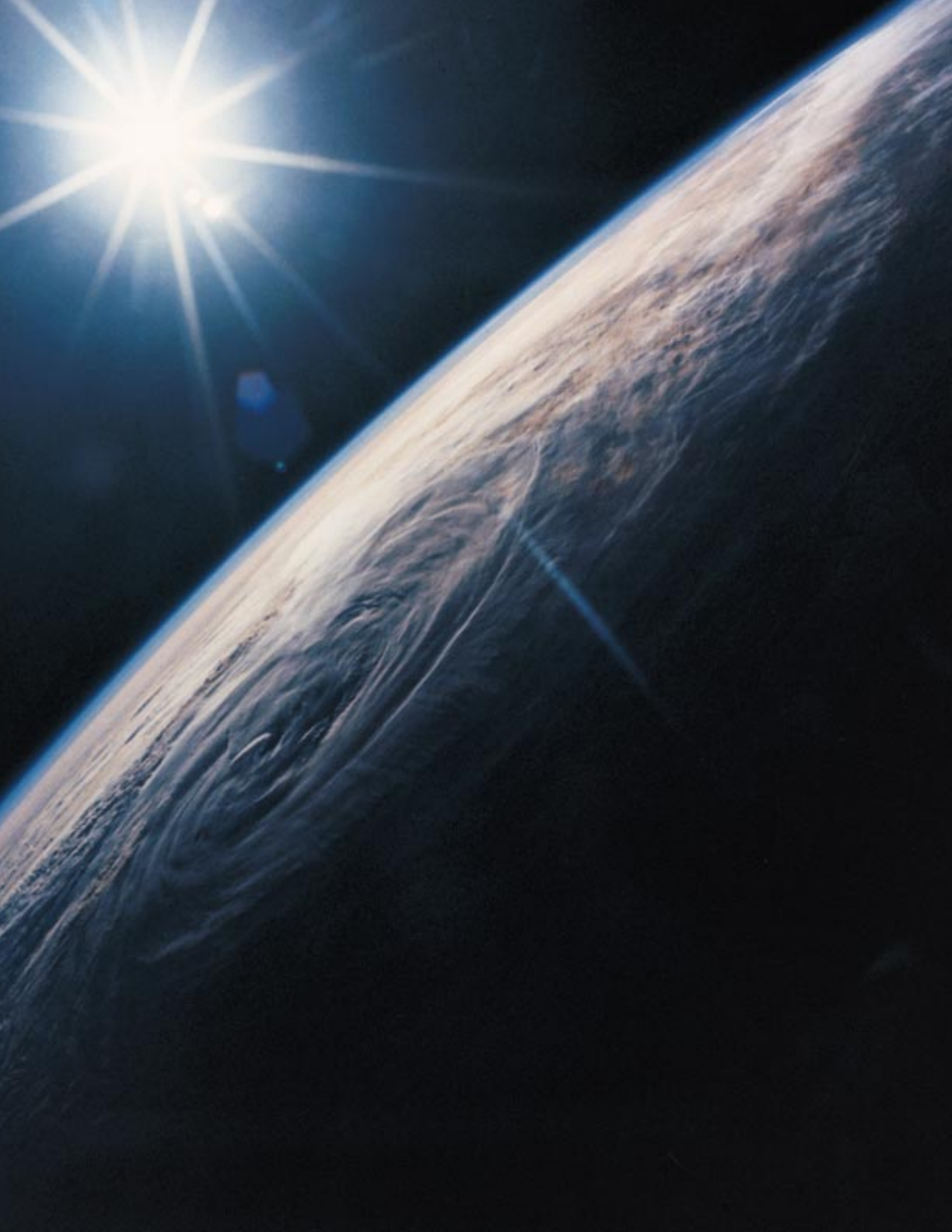


THE 1998 BMDO TECHNOLOGY APPLICATIONS REPORT

This report has been written and produced for BMDO by the National Technology Transfer Center, Washington Operations.

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INTRODUCTION

The collapse of the Soviet Union and the end of the Cold War have not brought an end to the need for a strong defense against ballistic missile attacks. Instead of facing a potential confrontation with a global nuclear power, the United States faces challenges that are different but no less complex: the spread of nuclear weapons and other weapons of mass destruction into new parts of the world. These new threats increase the need for a strong, active ballistic missile defense using only the most advanced weapon systems.

BMDO's MISSION



■ PAC-3 (pictured above) provides the lower tier of the BMDO architecture. Its capabilities include defending troops and fixed assets from short- and medium-range ballistic missiles, cruise missiles, and hostile aircraft. *Photo courtesy of Raytheon Systems Company.*

BMDO is using a layered approach to protect U.S. forces and allies against ballistic missile attacks. This approach focuses on three priority areas: (1) theater missile defense (TMD), to address the short-range, widely dispersed threat from short-range ballistic missiles; (2) national missile defense (NMD), to address the long-range threat from intercontinental ballistic missiles; and (3) advanced technology, to continue advancing BMDO's capabilities to counter more complex future threats from ballistic missiles. Each priority area is discussed below.

THEATER MISSILE DEFENSE

BMDO's TMD program concentrates on low-altitude defenses where short-range (theater) ballistic missiles that travel less than 2,100 miles are a major threat. TMD is designed to protect U.S. forces, allies, and other countries, including geographic areas of vital interest to the United States, from theater missile attacks. It has the highest priority of the three programs because the current theater missile threat poses the highest risk to U.S. forces.

TMD focuses on land- and sea-based defenses for a lower and an upper tier, basically defined by the altitude at which an intercept takes place, the speed of the interceptor, and the speed of the enemy missile. Lower-tier TMD programs include the Patriot Advanced Capabilities-3 (PAC-3), the Navy Area Defense, and the Medium Extended Air Defense System. Upper-tier TMD programs include the Theater High Altitude Area Defense system (THAAD), Navy Theater-Wide Defense (NTW), and Airborne Boost-Phase Intercept. BMDO's core TMD programs—PAC-3, Navy Area Defense, THAAD, and NTW—represented the bulk of BMDO's research and development, test and evaluation, and procurement budget in fiscal year 1997.

NATIONAL MISSILE DEFENSE

BMDO's NMD program focuses on high-altitude defenses, prompted by concerns that so-called rogue states might some day develop missiles with ranges long enough to reach U.S. soil. The NMD concept is to develop and demonstrate an intercontinental ballistic missile defense system by 1999, continue development thereafter, and if necessary deploy an initial capability as early as

2003. This degree of flexibility is critical if BMDO is to be prepared for any world situation.

BMDO is pursuing a fixed, land-based architecture for its NMD program. The planned system includes six fundamental building blocks: the ground-based interceptor; ground-based radar; upgraded early warning radar; x-band radars; space-based infrared systems; and battle management/command, control, and communications systems.

ADVANCED TECHNOLOGY

BMDO's Advanced Technology program supports research on new technologies and options for improving existing systems. These new ideas include advanced interceptor technologies (improved sensor windows, projectile structures, guidance and control systems, and seekers); directed energy technologies (chemical lasers); and advanced sensor technologies (Midcourse Space Experiment, focal plane arrays, laser radar, and image-processing algorithms). Such technologies are vital for BMDO to stay ahead of increasingly sophisticated ballistic missile threats.

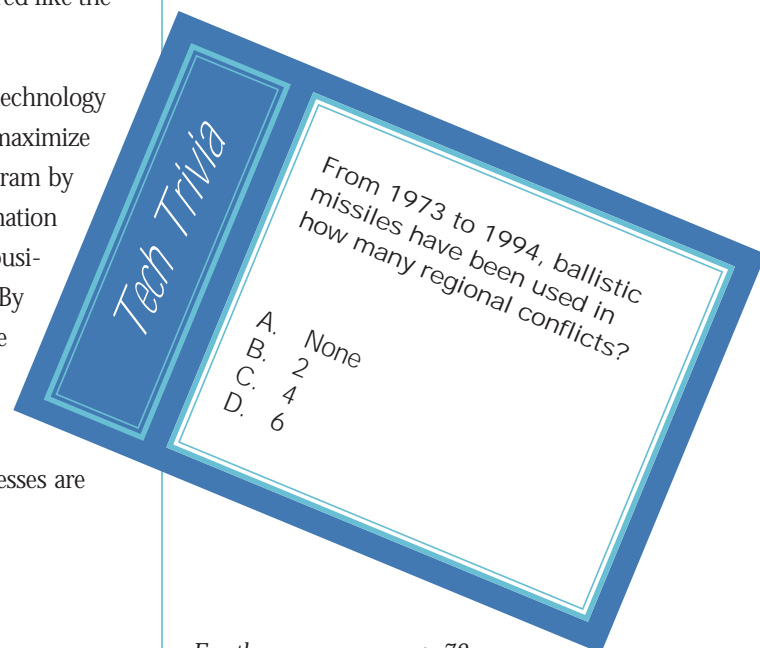
This program includes the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs. The SBIR program is designed to open the door to Federal research and development for small businesses and to speed the conversion of research findings to commercial products. Projects are funded in two competitive phases: In Phase I, the researcher demonstrates feasibility and develops a design concept; in Phase II, a prototype is built. The STTR program encourages cooperative joint research between businesses and nonprofit research institutions. It is structured like the SBIR program and operated by the same BMDO personnel.

Following the intent of Federal legislation, BMDO established a technology transfer effort—the Technology Applications (TA) program—to maximize research investments coming out of the Advanced Technology program by facilitating technology exchange. The TA program provides information about BMDO-developed technologies to U.S. corporations, small businesses, universities, entrepreneurs, and other government agencies. By doing this, it seeks to assist in the transfer of information between the developers of the technologies and those interested in using them.

BMDO has had many technology transfer successes in the 11 years since the TA program was founded. Some of the most recent successes are featured in this report.



■ Launched in 1996, the Midcourse Space Experiment (pictured above) is the first technology demonstration in space to characterize ballistic missile signatures during the important "midcourse" phase of flight between booster burnout and missile reentry.



For the answer, see page 72.

BMDO's TECHNOLOGY APPLICATIONS PROGRAM



■ Silicon Designs, which developed a miniature accelerometer for guiding BMDO interceptors, presented its business plan at a TA review and received commercialization feedback and guidance from the review panel. Today, the company's device is being used in the air bag systems (pictured above) of millions of Ford and Chrysler automobiles.

The TA program plays an important role in BMDO technology transfer by encouraging the commercialization of BMDO-funded technologies and widening their exposure to industry and the public. The program is implemented as a cooperative effort between BMDO and the National Technology Transfer Center, which provides an experienced group of technology transfer specialists with expertise in technology assessment, technology commercialization, intellectual property, and outreach. The following sections discuss the TA program's technology assessment and commercialization services as well as its latest outreach products and World Wide Web site.

BUSINESS FOCUS WORKSHOPS

Business Focus Workshops (BFWs) help small businesses implement a high-technology commercialization strategy for their BMDO SBIR or STTR Phase I projects. These one-day meetings help entrepreneurs translate research excellence into salable products. In a typical workshop, an SBIR project leader is linked with a technology transfer agent and a business consultant. This team creates a "business case" briefing; the researchers then present their cases to a panel of consultants for advice and feedback.

The 1997 workshops involved 22 SBIR companies. After their meetings, more than half of the companies asked for further assistance with issues raised during the workshops. Nine of these interactions produced specific company actions. For example, on the basis of a recommendation from one of the consultants, one company is considering an outside candidate for the post of chief operating officer.

The TA program expects many successful interactions to result from the 1998 BFWs, which involved 27 SBIR and STTR businesses. It is currently surveying the businesses that attended these workshops while preparing for next year's BFWs.

TECHNOLOGY APPLICATIONS REVIEWS

TA reviews are catalysts for the commercialization of BMDO-funded technologies. At these reviews, research and development professionals present summaries of their technologies for commercialization. Reviewers from industry, government, and universities respond to the presentations with opinions on new applications, commercial strategies, and technology transfer opportunities. The researchers then use this expert advice to shape their businesses, potentially making them more profitable and commercially driven.

Since 1989, roughly 375 researchers have presented their commercialization strategies to panelists in more than 54 TA reviews. In 1998, the review process focused on space, medicine, photonics, manufacturing, and electronic materials technologies. In previous years, reviews have focused on energy, networks, nanotechnology, and intelligent transportation.

OUTREACH PUBLICATIONS

An important part of the TA program's mission is raising industry and public awareness of BMDO-funded technologies with high commercial potential. The developers of BMDO-funded technologies often lack the funds to publicize their achievements. When these technologies cannot attract industry's interest, many of them wind up collecting dust on laboratory shelves.

To help gain visibility for these technologies, the TA program produces several types of outreach publications. For example, to reach those who may want to use BMDO technology, the TA program publishes a quarterly newsletter called the *BMDO Update*. The newsletter is a major component of BMDO's technology push efforts, featuring BMDO innovations that already are being commercialized or that have potential commercial applications. With more than 26 issues and 465 stories published since 1991, the *BMDO Update* has received and responded to more than 18,000 requests for information.

The TA program also focuses on areas where BMDO-funded technologies have high commercial potential and could significantly improve a particular U.S. industry. To highlight these areas and technologies, it produces detailed applications reports. Recent reports include *BMDO Technology and the Electric Utility Industry*; *BMDO Technologies for Biomedical Applications*; *BMDO Technologies—Improving the Environment*; and *BMDO Fiber-Optic Technologies for Telecommunications*. The TA program also produces the *Technology Applications Reports*, which features the top commercial success stories emerging from BMDO research and development efforts.

WORLD WIDE WEB SITE

To share information quickly and affordably with a large audience, BMDO has developed a World Wide Web site called BMDOLINK (<http://www.acq.osd.mil/bmdo/bmdolink/html/bmdolink.html>). This site features a wide range of BMDO news and information, including fact sheets, media briefings, and congressional testimonies.

BMDOLINK also has a technology transfer section (<http://www.acq.osd.mil/bmdo/bmdolink/html/transfer.html>). Updated periodically, this section features background information on the TA program, a multimedia library, and commercialization success stories. It also contains online versions of several BMDO technology transfer publications, which can be either downloaded or viewed online.



■ The *Update* newsletter (pictured above) spreads the word about all types of BMDO-funded technology with high commercialization potential. Applications reports, however, are more focused. The latest report, *BMDO Technologies—Improving the Environment* (pictured above), speaks to the important ways that BMDO technology has a direct impact on the environment.

FOR COPIES OF ANY PROGRAM PUBLICATION MENTIONED IN THIS SECTION, CONTACT THE NATIONAL TECHNOLOGY TRANSFER CENTER, WASHINGTON OPERATIONS. MAIL, TELEPHONE, FAX, AND E-MAIL INFORMATION IS PROVIDED ON THE INSIDE FRONT COVER OF THIS REPORT.





COMMUNICATIONS AND NETWORKING TECHNOLOGIES

Think of BMDO technology
transfer the next time you

- Call someone from a portable telephone.
- Make a telephone call from or to a very remote location.
- Need a fast way to send a large amount of digital information across town.
- Access the Internet.

WIRELESS, LIKE YOU NEVER HEARD IT BEFORE

Intelligent, adaptive signal processing can enhance wireless communications, helping to increase system capacity and improve signal quality.



■ ArrayComm's IntelliCell® technology is the driving force behind a new generation of intelligent base stations (pictured above) soon to be deployed widely in the Japanese market.

Take a mobile car phone, and shorten its range. What you have is a lot like the service provided by low-mobility wireless systems, the next big thing in telecommunications. These systems are intended for customers who need “walkaround” wireless access in a limited geographic area, such as a local neighborhood or business campus.

Unfortunately, some drawbacks, such as interference and capacity, have limited the growth of this wireless service. For example, in densely populated areas, crosstalk from other cellular signals can seriously degrade signal quality. Multipath interference, caused by the physical features of the urban landscape, also distorts signals.

ArrayComm, Inc. (San Jose, CA), is marketing systems that enhance wireless communication systems by maximizing signal quality while minimizing interference. Using BMDO-funded advanced radar signal-processing technology that originated at Stanford University, ArrayComm has developed a suite of algorithms to discriminate between multiple radio signals operating on the same frequency. The technology, called IntelliCell®, selectively receives radio-frequency energy from, and transmits it to, multiple users in the same “cell” simultaneously.

Virtual wires. The IntelliCell process creates “virtual wires” that establish and maintain optimal connections between each subscriber and a base station. The key technologies consist of a methodology for siting multiple transceiver antennas, algorithms for processing the signals from the array, and software to control the signal processing functions. By applying intelligent control of the individual antennas, the system can selectively transmit radio frequency (RF) signals to the receiver; it can also selectively “listen” to the mobile transmitter, mitigating interference signals from other RF sources.

“IntelliCell techniques dramatically enhance wireless service quality, coverage, and capacity on a real-time basis,” says ArrayComm’s Dr. Richard Roy, the scientist who spearheaded the original technology development at Stanford. “The result is an unprecedented savings in infrastructure and operating costs.” ArrayComm reports that because fewer base stations are needed, IntelliCell can help reduce infrastructure investments by up to 50 percent over conventional

base station approaches. Operating costs, such as those associated with power and equipment maintenance, would also be reduced.

In its first commercial application, IntelliCell technology is being deployed in Japan's Personal Handyphone System (PHS), a low-mobility personal communications system introduced in 1995. PHS is marketed on its low-cost, high-quality service; lightweight handsets; and long battery life—all attributes that IntelliCell technology can further enhance. Collaborating with Kyocera Corporation in Japan, ArrayComm initially incorporated IntelliCell technology into 30 base stations in Tokyo for Kyocera's customer, DDI Pocket Telephone, the largest PHS service provider in Japan. Test results pointed to superior voice quality with an estimated four- to five-fold increase in network capacity. Full-scale deployment is under way.

Ever so popular. With the success of the testing program, ArrayComm and Kyocera recently finalized an agreement to manufacture and commercialize IntelliCell-equipped base stations. DDI also placed an order for 1,000 such units. DDI Pocket provides service for an estimated 3.5 million Japanese subscribers, making it the largest PHS carrier in the world. In addition, Kyocera currently ranks first of 16 manufacturers in the PHS handset market, with a 25 percent share.

In the longer term, ArrayComm projects an expanding market share for wireless local loop (WLL) systems to more than half the entire wireless business volume by the year 2000. WLL products are intended for rapid deployment of local telephone services in less-developed countries lacking wire-based telephone switching networks. They enable many telephones in a local area to communicate using a single base station. Because WLL can be easily installed, it is particularly attractive for use in rural settings.

ArrayComm is now marketing an IntelliCell WLL system called IntelliWave especially for this remote market. The company has established relationships with strategic partners in Asia, Europe, and South America. For example, it recently signed a partnership agreement with Brazil-based Zetax Tecnologia S.A. (ZETAX) that establishes ZETAX as a distributor of ArrayComm's IntelliWave product in Brazil.

■ For more information, contact Christine M. Oliver via telephone at (408) 428-9080 or via E-mail at chriso@arraycomm.com. You can also visit ArrayComm's Web site at <http://www.arraycomm.com>.



What Does It Mean to You?

IntelliCell technology will sound great to wireless subscribers because it reduces static and interference and ultimately lowers handset and service costs.



What Does It Mean to Our Nation?

With its performance, range, and cost advantages, IntelliCell technology could help U.S. wireless providers thrive in this intensely competitive market.

Tech Trivia

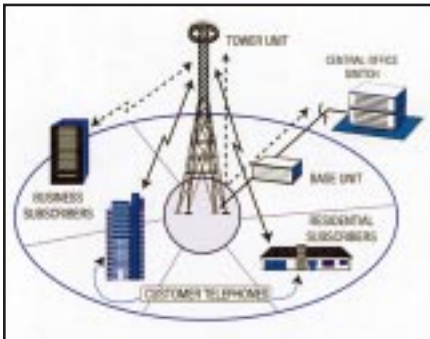
At the Olympic games in Atlanta, Georgia, what were the 21 cellular stations that roamed the premises called?

- A. COWs
- B. HOGs
- C. LAMBS
- D. PIGs

For the answer, see page 72.

THE WIRELESS FUTURE IS—GUINEA?

A fixed wireless telephone network can help telecommunications companies reduce infrastructure costs in rural areas of developing countries.



■ Glynn Scientific's wireless telephone network (pictured above) can serve rural areas of any size up to 11,300 square miles.

Despite technology advances, tens of millions of people in developing countries have little or no access to basic telephone services. One-quarter of the world's population of 5.9 billion lives in countries where there is less than one phone line for every 100 people, which the International Telecommunications Union, a United Nations agency, defines as "minimum access." In countries like Afghanistan, Guinea, and Somalia, there is just one telephone for every 500 people.

In developing countries, roughly two-thirds of the population lives in rural areas, making it costly for telecommunications companies to justify their infrastructure investment. In these countries, the cost to connect each subscriber could easily surpass \$1,000, nearly double the cost in more developed nations.

Glynn Scientific, Inc. (GSI; Annapolis, MD), is creating a new wireless network technology called Towerphone™ that may reduce new subscriber connection costs to as low as \$200. By combining an innovative communications signaling technology with fixed towers, this network technology can provide low-cost, high-quality telephone and data services to more than 1 million subscribers. Single-tower Towerphone networks can serve areas of any size up to approximately 11,300 square miles. Service will be provided using low-cost subscriber phones.

Bandwidth economy. The key to Towerphone is its communications signaling technology called convolutional ambiguity multiple access (CAMA), which offers several advantages in multiple-access telecommunications environments. CAMA can permanently assign unique codes to all subscribers, reducing the amount of bandwidth consumed in the call set-up process. It also offers acceptable co-channel interference performance without network-wide synchronization—a major simplification in network design. GSI developed CAMA while working on advanced phased-array radar technology for BMDO's Arrow and Corps Surface-to-Air Missile projects and on other defense projects.

Towerphone will be attractive to telephone companies looking to break into emerging telecommunications markets in developing countries around the globe. "With a projected subscriber connection cost of \$200, Towerphone will minimize infrastructure outlay and help bring in profits sooner for telecommunications companies," says Tom Fullerton, GSI's vice president of business

development. "You won't get this level of pricing with cellular or very small aperture satellite terminal (VSAT) technology. Cellular pundits say a \$500 subscriber connection cost is possible within the next few years. And the current subscriber connection cost for VSAT reaches between \$3,000 and \$5,000."

Mr. Fullerton also points out that Towerphone requires less infrastructure than cellular networks. Capable of covering the same area as a Class A television station, Towerphone requires only one fixed tower, while cellular service requires "a whole bunch." The television station reference is appropriate because Towerphone will use existing television transmission towers for mounting equipment wherever possible. In addition, businesses and homes will not need any huge dishes or bulky equipment; the antenna will be a small, flat plate that can be easily attached to the side of a building.

On the move. GSI has developed an in-depth business plan for bringing Towerphone to market. With the assistance of an international investment banking advisory team, the company is currently seeking financing to begin product development. It is seeking \$8 million to install and test a 1,500-subscriber beta-site network in the United States or abroad.

Further leveraging BMDO-related technology, GSI has spun off a new venture company called NetSat28. In May 1997, NetSat28 received a Federal Communications Commission license to develop and launch a communications satellite to operate in the K and Ka microwave bands, averaging 28 gigahertz in uplink carrier frequency. The geostationary satellite will enable coast-to-coast, two-way communications at conventional T1 network data access rates, or 1.5 megabits per second. Based on patented optical switching technology, NetSat28 could provide as many as 175,000 two-way links simultaneously, offering speedier access to the information superhighway.

To date, the NetSat28 team has invested \$1 million of internal funds to form NetSat28, secure the Ka-band license, and continue technical development at GSI. With the satellite's launch date set for 2002 or 2003, the company is exploring relationships that will exploit this exciting capacity for both business and home use. NetSat28 seeks content and service providers who could also benefit from this network infrastructure.

■ For more information, contact Tom Fullerton via telephone at (410) 268-6981 or via E-mail at tfullerton@glynn-scientific.com.



What Does It Mean to You?

Towerphone will allow Americans to communicate with people in developing countries (and vice versa) as easily as making a telephone call in the United States.



What Does It Mean to Our Nation?

New international companies anchored in the United States can be formed to market Towerphone technology to emerging telecommunications businesses in developing countries around the world.

Tech Trivia

When Alexander Graham Bell died on August 4, 1922, what happened later that day?

- A. Millions of phones went dead.
- B. He was buried holding a telephone.
- C. His wife permanently removed all telephones from their home.
- D. His native country Canada commissioned a statue to be built in his honor.

For the answer, see page 72.

LASER AIMS TO SHOOT DATA THROUGH THE AIR

Fiber-free laser communications systems allow companies to transmit data through the air, connecting multiple building sites at an affordable cost.



■ AstroTerra's newest product, the TerraLink 1000™ (pictured above), provides low-cost, fast data rate laser communications for distances under a mile.



■ A TerraLink 8-155™ (pictured above) provides high-speed wireless connectivity between the Las Vegas Convention Center and the Hilton Hotel.

The city of Santa Barbara, California, is ever vigilant to enforce strict regulations against altering historic buildings and city streets. That is what STAR Telecom, a provider of wholesale international long-distance telephone services, found out soon after the company decided to expand its corporate local area network. The city's aesthetic ordinances banned any effort to trench fiber across the street or to install large microwave antennas on buildings. Thus, STAR Telecom could not establish a network connection to its other downtown building.

Thanks to new laser communications (lasercom) equipment developed by AstroTerra Corporation (San Diego, CA), STAR Telecom established a low-cost, high-bandwidth connection between its two buildings—without disturbing the historic land and buildings. AstroTerra's cutting-edge lasercom technology, called TerraLink™, is ideal for meeting the ever-increasing demand for greater bandwidth among multiple buildings at an affordable cost. For corporate network managers, this innovation provides a new alternative to fiber, microwave, and radio frequency (RF) technologies, which in some cases can be too expensive, too complex, and too low in bandwidth.

Through the air. AstroTerra's lasercom systems use infrared (IR) laser light to transmit the 1s and 0s that make up a digital signal. This process is similar to the one that takes place inside a fiber-optic cable, but for laser communications, the light travels through the air. AstroTerra spun off its lasercom technology from a BMDO-funded project to develop a satellite lasercom transceiver, which is scheduled to be lofted into low-Earth orbit in early 1999 as part of BMDO's Space Technology Research Vehicle (STRV)-2 experiment. In STRV-2, the transceiver will be used to demonstrate communication between the satellite and the ground at 1 gigabit per second as well as to downlink IR sensor data.

TerraLink systems provide new alternatives to installing fiber-optic cable between sites. "For high-bandwidth applications such as telemedicine or video-conferencing, TerraLinks are more attractive when it is too costly or impossible to install fiber-optic cable," says Dr. Eric Korevaar, AstroTerra's founder and president. "For situations that require temporary network connectivity, such as exhibitions, conventions, sporting events, or emergency situations, high-bandwidth links can be easily and quickly provided using portable TerraLink systems. With

private corporate networks, purchasing a TerraLink can provide a very high bandwidth link between sites without the recurring costs of leased lines.”

TerraLink products offer bandwidth, operation, and security advantages over microwave and RF technologies. TerraLink systems transmit data faster than any currently available microwave or RF system. They do not require a frequency license from the Federal Government or right-of-way from the municipality involved. In addition, their IR beams are invisible and confined to a narrow path, thus making them difficult to intercept.

Several TerraLink products are commercially available. The basic TerraLink 8-155™ can transmit and receive data at up to 155 megabits per second (Mbps), with a clear weather range of up to 5 miles. The faster TerraLink 8-622™ allows a data rate of 622 Mbps—which exceeds the current bandwidth capabilities of microwave—at clear-weather distances of up to 3 miles. The TerraLink 4-155™ and TerraLink 1000™ offer the same connectivity as the TerraLink 8-155 but cost less because they are designed for distances less than a mile.

Purchases and evaluations. A number of municipal and commercial organizations have purchased or are currently evaluating TerraLink products. The San Diego County Water Authority installed a TerraLink system to establish a high-speed data link between two office buildings in downtown San Diego, California. The Authority says it saved a substantial amount of money because it avoided the costs of trenching cables across the street and leasing lines between the two buildings. Kaiser Permanente’s Technology Evaluation and Support Center is currently evaluating TerraLink for use in its health care facilities throughout California.

In addition, AstroTerra is investigating several military applications for its TerraLink technology. The company is involved in tests for ship-to-ship and ship-to-shore communications for the U.S. Navy, site-to-site communications for the U.S. Army, and unmanned aerial vehicle communications for the U.S. Air Force.

Another potential market, space communications, may be pursued if BMDO’s STRV-2 demonstration of AstroTerra’s lasercom technology is successful. To attract prospective customers, AstroTerra is building a lasercom evaluation model with a data rate greater than 1 gigabit per second for satellite-to-satellite and satellite-to-ground links.

■ For more information, contact Eric Korevaar via telephone at (619) 792-8501 or via E-mail at korevaar@astroterra.com. You can also visit AstroTerra’s Web site at <http://www.astroterra.com>.



What Does It Mean to You?

Lasercom systems will establish secure, high-bandwidth connections between two or more nearby buildings, allowing workers to communicate more efficiently with each other.



What Does It Mean to Our Nation?

Lasercom systems will help municipalities preserve historic streets and buildings while allowing companies to expand communications networks.

Tech Trivia

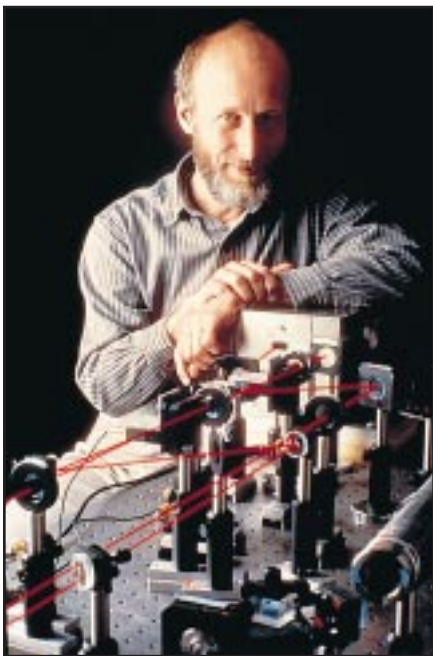
In which of the following novel applications have infrared lasers not been used?

- A. Security
- B. Eye surgery
- C. Aircraft inspection
- D. Three-dimensional imaging

For the answer, see page 72.

OPTICAL SWITCH PUSHES THE DATA ENVELOPE

An optical switch that transports many more bits of data per second will pave the way for speedier Internet connections and movies-on-demand.



■ Pictured above is Dr. Thomas Mossberg, chief technology officer, who believes Templex's optical technology will route data signals faster than current technologies.

Everything carried on optical fiber, whether a phone call, a data file, or video, starts out as electrical impulses. Before these impulses can enter the fiber, they must be converted to optical form. Today, that conversion is done at the local phone company office, using a costly computer—or switch—that modulates a laser so that variations in the light carry the signal. The difficulty comes in separating those different messages to deliver them to their ultimate destination.

Templex Technology Corporation (Eugene, OR) has developed an optical switch that can make this transfer more quickly, increasing the speed of communications. Called SmartSwitch, this technology operates up to 100 times faster than current switches, making it possible to route the equivalent of 500 complete sets of the *Encyclopedia Britannica* in 1 second. This speed increase will save time and money for people and businesses that frequently rely on the Internet as a source of information. Immediate benefits could include cheap two-way videoconferencing and the delivery of movies-on-demand to the home.

Superfast routing. Underlying SmartSwitch technology are unique proprietary encoder/decoder devices that generate and detect ultrahigh-speed optical data packets. The encoding device uses a form of code division multiple access (CDMA) to transmit groups of data bits through multiple channels on a single fiber, with each bit assigned a unique sequence code. These data bits are then funneled through a decoder device, which either continues transmitting them along each channel or selectively reroutes them to new destinations. BMDO's SBIR program funded the development of SmartSwitch technology for new high-speed, all-optical data communications networks.

SmartSwitch optical switching devices are simple in design and cheaper than competing devices. "Templex's CDMA provides multiple communication channels with a single laser source," says Dr. Thomas Mossberg, Templex's chief technology officer. "Competing technologies such as wavelength division multiplexing (WDM) systems, for example, use multiple lasers. In addition, because SmartSwitch uses only one laser, it will be much more reliable than WDM systems."

Templex says there is an enormous potential for SmartSwitch in telecommunications. Telephone and cable TV companies have installed 25 million miles of

fiber-optic cable in the United States and are adding thousands of miles a day. Hundreds of thousands of optical switches are needed to direct traffic on these cables. Templex is discussing potential manufacturing deals with several major telephone companies.

In addition to an optical switching device, Templex is developing an optical dynamic random access memory (ODRAM) product. About the size of a regular 3.5-inch diskette, ODRAM will be capable of providing 100 gigabytes (one billion bytes) of storage capacity with entirely nonmechanical beam steering, resulting in data access times of microseconds (millionths of a second) rather than milliseconds (thousandths of a second) common in magnetic disk storage technology today. It also promises multigigabit-per-second read and write rates.

Capacious memory. Templex's ODRAM technology will be faster than traditional semiconductor random access memory (RAM) and have a greater storage capacity than magnetic media or compact disc read-only memories (CD-ROMs). For example, ODRAM will store up to 100,000 bits of information per spot, compared with CD-ROM's 1 bit per spot. Businesses and government agencies that must quickly access reams of small, individual records could benefit from using Templex's technology. Possible users include banks, insurance companies, libraries, the Internal Revenue Service, and the Social Security Administration.

An ODRAM prototype has recently been completed. It stores between 50 and 100 gigabytes of data at a cost ranging from \$250 to \$500 per gigabyte. Templex is discussing market opportunities with a major data storage system supplier.

In 1995, Templex received start-up funding from Cascadia Pacific Management and the Oregon Technology Development Fund. Recently, the company concluded a venture capital round of financing with a group of prominent U.S.-based high-technology investors, bringing the firm's total capital infusion to over \$5 million. "The new capital funding brings not only additional financing to the firm, but also a broad base of knowledge from its new investors that will drastically shorten time lines for development of our products," says Larry Brice, Templex's president.

■ For more information, contact Dr. Thomas Mossberg via telephone at (541) 683-7474 or via E-mail at mossberg@templex.com. You can also visit Templex's Web site at <http://www.templex.com>.



What Does It Mean to You?

Optical switches will help reduce traffic bottlenecks along the information superhighway, enabling the Internet to emerge as a full-blown service or utility carrying many types of media.



What Does It Mean to Our Nation?

Optical switches will speed the creation of Internet commerce, boosting our country's technological edge in the global marketplace.

Tech Trivia

One of the biggest congestion spikes on the Internet can be attributed to NASA's World Wide Web coverage of which event?

- A. The collision of Comet Shoemaker-Levy with Jupiter
- B. The landing of a spacecraft on Mars
- C. The discovery of ice on the moon
- D. The destruction of the space shuttle Challenger

For the answer, see page 72.



ENERGY TECHNOLOGIES

Think of BMDO technology transfer the next time you

- Drink water or soda at a restaurant.
- Visit a solar-powered home.
- Turn on your car's air conditioner on a hot day.
- Turn on a light switch or pay your power bill.



ZAPPED! CAPACITORS CHARGE AGAINST MICROBES

High-energy capacitors zap pathogenic microbes to purify water, sterilize pharmaceutical products, and reduce bacteria levels on foods.



■ A large international food chain will use PurePulse's PureBright® system (pictured above) to decontaminate water.

You may not recognize its tongue-twisting scientific name. But you might remember *Cryptosporidium* was the “bug” that made Milwaukee famous.

In this city during the summer of 1993, a major outbreak of the waterborne parasite occurred, sickening more than 400 people. By the time the outbreak ended, 100 people had died. It was the largest episode of waterborne disease in the United States in the 70 years since health officials began tracking such outbreaks.

PurePulse Technologies, Inc., a subsidiary of Maxwell Technologies, Inc. (San Diego, CA), has developed a fast and efficient method for eliminating deadly bacteria, viruses, and other microorganisms, including *Cryptosporidium*. Dubbed PureBright®, this system uses concentrated energy in short, high-intensity pulses to rupture the membranes of pathogenic microbes without using heat, chemicals, or ionizing radiation. Based on advanced high-energy capacitors, the system offers kill rates 100 to 10,000 times those of conventional mercury lamp ultraviolet treatments.

A little zap will do. Capacitors, the key to PureBright technology, accumulate electrical charge and energy on the surfaces of conducting plates that are insulated from each other by a dielectric material. Maxwell developed its capacitors by using insulating materials with a higher dielectric constant, reducing the thickness of the material, increasing the voltage between conductors, and reducing the thickness of the conducting plates. BMDO partially funded development of these capacitors to produce a compact, lightweight device that could provide pulsed power for space-based lasers and accelerators.

PureBright is highly effective in killing microorganisms such as vegetative bacteria, yeasts, molds, bacteria spores, and viruses. “The light does not penetrate opaque materials, but is transmitted through many types of clear packaging materials, fluids, and air,” says Kent Salisbury, Maxwell’s PurePulse program manager. “PureBright’s extremely short exposure time greatly reduces the potential for material degradation. The treatment is a clean process, leaving no chemical residues and requiring no evacuation steps.”

PurePulse is aggressively capitalizing on its unique PureBright technology in the commercial marketplace by forming alliances and establishing licenses. For

example, the company has teamed with Tetra Pak and Automatic Liquid Packaging to commercialize the PureBright process for food and pharmaceutical packaging applications, respectively. In another example, PurePulse and a major manufacturer and marketer in the health care field agreed to pursue a licensing and purchase agreement to use PureBright technology for sterilizing certain disposable consumer products. This agreement involves technology rights and the purchase of several PureBright systems, with a value over \$2 million over the next several years.

The company recently found a new market for PureBright technology—water purification. Thanks to a \$1 million grant from a large international food chain, PurePulse has developed a system that can clean 4 gallons of water a minute and easily fit into commercial kitchens. The system will allow restaurants to serve their customers safer water, hot and cold beverages, and ice cubes. With field testing nearly complete, the water purifier will soon be available on the market.

Ultrapure water. PurePulse is also making significant inroads in industry. In early 1998, the company signed an agreement with Pall Corporation that could lead to the commercialization of its PureBright technology for producing high-purity water for the semiconductor industry. According to PurePulse, the market for ultrapure water for semiconductor manufacturing and other industrial scientific applications is estimated to be over \$200 million.

High-energy density capacitors similar to those used in PureBright systems also have been incorporated into heart defibrillators that deliver an electrical current (a shock) to a heart in cardiac arrest. The defibrillator interrupts the heart's chaotic heart rhythm, known as ventricular fibrillation, allowing it to stop very briefly and begin beating again rhythmically; the sooner the heart can be defibrillated following cardiac arrest, the greater the patient's chance of survival. Maxwell has developed four types of external heart defibrillators and annually sells about 20,000 of them to 10 original equipment manufacturers.

■ For more information, contact Kent Salisbury via telephone at (619) 576-7526 or via E-mail at kent@purepulse.com. You can also visit PurePulse's Web site at <http://www.purepulse.com>.



What Does It Mean to You?

Short, intense pulses of light can help eliminate deadly bacteria, viruses, and other microorganisms, allowing restaurants to serve safer drinking water, hot and cold beverages, and ice cubes.



What Does It Mean to Our Nation?

Pulsed-power technologies are being used more often to purify water, helping stave off widespread outbreaks of *Cryptosporidium* and other deadly microorganisms.

Tech Trivia

In which of the following has *Cryptosporidium*, an emerging threat to the U.S. water supply, not been found?

- A. Food
- B. Bottled spring water
- C. Swimming pool water
- D. Surface waters (rivers, lakes, etc.)

For the answer, see page 72.

TAPPING THE SUN IN THE NEXT MILLENNIUM

An optical lens device concentrates sunlight onto solar cells, providing cost savings for photovoltaic systems powering spacecraft and homes.



■ SCARLET™ technology (pictured above) concentrates light to the strength of many suns onto a small area of solar cells.

How expensive is it to use solar electricity to power next-generation communications satellites? Even though sunlight is inexhaustible and free, a conventional satellite solar cell array that generates 15 kilowatts (kW)—enough power to heat a small house—can cost as much as \$20 million to build. Furthermore, because of their bulky, rigid designs, these arrays can significantly increase a satellite's launch costs.

ENTECH, Inc. (Keller, TX), has developed an optical lens device, called the line-focus Fresnel lens, that could save millions of dollars in deployment costs for solar-powered spacecraft. The lens reduces the amount of solar cell material needed to produce a given amount of power by a factor of 10. Because considerably less cell area than is required with conventional arrays, tremendous weight and cost savings can be realized. In addition, because of its light concentration effects and ability to use cell material optimized for the focused wavelengths, the lens greatly enhances power efficiencies.

Magnifying glass. Like a magnifying glass, the lens captures, funnels, and concentrates sunlight. Its cylindrical design has a smooth outer surface and an inner surface made of microscopic prisms that shape the light with a much higher efficiency than previous solar concentrator designs. BMDO, which initially funded ENTECH's design concept through an SBIR contract, is funding further research and development on the lens for the Solar Concentrator Array with Refractive Linear Element Technology (SCARLET™) program.

ENTECH and AEC-Able Engineering Company, Inc. (Goleta, CA), have developed two lens designs, SCARLET I and II, for future advanced space power applications. Although the METEOR I launch vehicle carrying SCARLET I failed 45 seconds after its October 1995 launch, another SCARLET array, which has been further enhanced, was chosen for NASA's New Millennium Deep Space 1 (DS1) spacecraft, which was launched in October 1998.

Two SCARLET II solar wing assemblies consisting of 720 ENTECH line-focus Fresnel lenses will power the DS1 spacecraft and its revolutionary ion thrusters. This mission will mark the first time that ion propulsion, rather than chemical-based propulsion, is being used as a primary means to propel a spacecraft. Once proven to work, solar-powered ion thrusters will enable next-generation spacecraft to travel 10 times faster than those using chemical propellant systems.

Buying more sun for the dollar. SCARLET II solar arrays can provide spacecraft makers with a tremendous cost savings. "In a recent study, AEC-Able found that SCARLET II technology could save an estimated \$9 million to \$13 million when it is used to replace a conventional 15 kW gallium arsenide on germanium array," says Mark O'Neill, ENTECH's president. "That's a savings of \$600 to \$900 per watt of array power, which enables companies to buy a lot more sun for their dollar." ENTECH has an exclusive agreement with AEC-Able for the space-based concentrator. The team hopes to capture a large portion of the communications satellite market, and by using SCARLET II technology, hopes to significantly reduce solar array costs. A more compact third-generation SCARLET array is currently being developed.

In addition, ENTECH is pursuing terrestrial applications for its solar concentrator. For example, its SolarRow product is designed to provide renewable electrical power with zero emissions for utility-scale applications. In late 1996, ENTECH was selected by a team led by Nevada Power Corporation to provide large-scale solar power plants for the Solar Enterprise Zone (SEZ) in Nevada. The SEZ project could result in 20-megawatt capacity of ENTECH equipment installed and operating in the Nevada desert within the next five years. In the Southwest, two electric utilities have recently built 100 kW power plants using ENTECH SolarRows.

The company's SUNLINE™ stand-alone power units can supply power for small or remote electricity demands. These units can offer a clean, quiet, non-polluting, renewable power source for a wide range of applications, including lights, water pumps, small villages, remotely located homes, and water purification systems.

■ For more information, contact Mark O'Neill via telephone at (817) 379-0100 or via E-mail at moneill@startext.net. You can also visit ENTECH's Web site at <http://www.entsolar.com>.



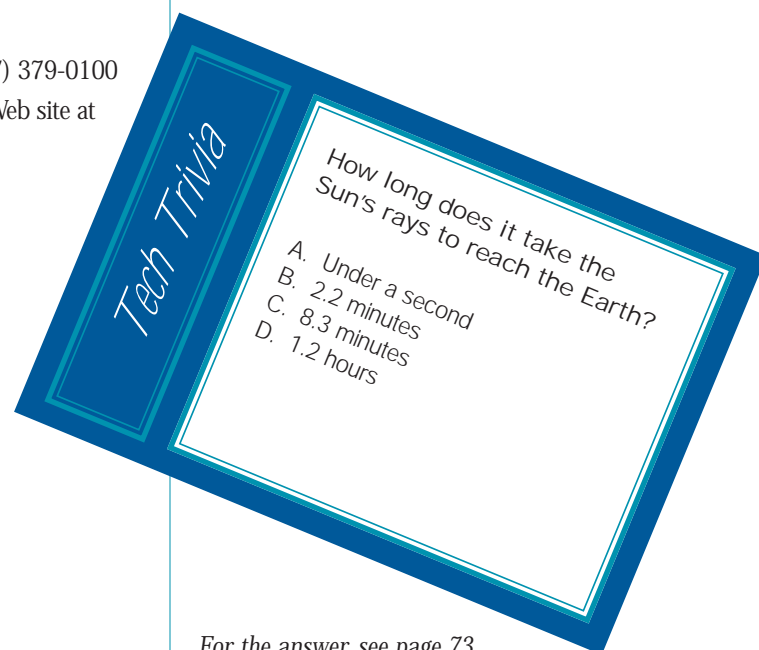
What Does It Mean to You?

Fresnel lenses increase solar cell efficiency and reduce array costs, bringing solar electricity one step closer to reality as a cheap, pollution-free power source for homes and businesses.



What Does It Mean to Our Nation?

By enabling cheaper, more powerful spacecraft, solar concentrators will help facilitate the launch of communications satellites and U.S. Government-sponsored exploratory spacecraft.



For the answer, see page 73.

LIQUID ADDITIVE IS COOL FOR AIR CONDITIONERS

A liquid additive for air conditioners, heat pumps, and refrigeration systems improves cooling performance by boosting capacity and efficiency.



■ QwikBoost™ (pictured above) is expected to increase the cooling capacity of automobile air conditioners by 10 percent and cool the passenger space of vehicles faster than existing technology.

On hot days, does your car feel more like an oven? Summer heat can raise temperatures to dangerous levels, especially inside a car. And many people do not realize how quickly a car's interior can heat up—even with the windows down several inches. For example, when the outside temperature is 83°F, the temperature inside your car can reach 109°F in just 15 minutes.

Unfortunately, there is little to keep you from roasting before the air conditioning kicks in. And, once it does, the supply of cool air never seems to be enough.

This summer, automotive air conditioners will be better prepared to beat the heat, thanks to a liquid performance additive developed by Mainstream Engineering Corporation (Rockledge, FL). Called QwikBoost™, the new additive is expected to boost cooling capacity by 10 percent. It will also cool the interior of vehicles faster than existing technology. Mainstream Engineering has packaged its additive and a small quantity of R-134a refrigerant in a single-dose 3-ounce can, soon to be available at local automotive supply outlets.

Easy work. When added to a vapor compression air conditioner, heat pump, or refrigeration system, the additive significantly improves the coefficient of performance (COP) of the system, thereby reducing its energy consumption. The COP is a measure of system efficiency as indicated by the ratio of cooling output to the input energy. QwikBoost circulates through the refrigeration system with the working fluid. It increases the available cooling capacity (latent heat) of the refrigerant during the evaporation process, thereby resulting in better performance.

Mainstream Engineering developed the initial technology under BMDO SBIR contracts for advanced heat pumps for spacecraft heat rejection systems. This effort evaluated four heat pump configurations for use as spacecraft heat rejection systems. One of these system evaluations, based on a chemical/mechanical heat pump, led to the development of the performance-enhancing additive. Subsequent development work was performed under NASA and Air Force SBIR contracts.

One concern about using liquid additives in air conditioning equipment has been whether these products adversely affect system lubrication or compressor life. "Lubrication tests, performed at an independent laboratory, and compressor life tests have indicated that QwikBoost does not adversely affect compres-

sors,” says Larry Grzyll, Mainstream Engineering’s senior chemical engineer. “In fact, test results show that a QwikBoost/lubricant mixture produces less wear than the pure polyol ester refrigeration lubricant typically used in today’s refrigeration systems.”

Another benefit of QwikBoost is that it enhances air conditioner performance without adversely affecting the environment. A few years ago, environmental regulations forced automobile manufacturers to replace systems using R-12 air conditioner coolant, which contains chlorofluorocarbons, with less-polluting systems using R-134a coolant—a move that left consumers underwhelmed with the lower performance of the new and retrofit systems. Mainstream is marketing QwikBoost as a solution to these performance problems. Of the 150 million air-conditioned cars on the road today, roughly 90 million still use R-12 coolant.

Award winner. Mainstream Engineering has a strong and ongoing commitment to commercializing QwikBoost. The U.S. Small Business Administration has recognized this commitment and honored the company with one of its annual Tibbetts Awards in 1997. The Tibbetts Awards recognize superior SBIR technological innovation, economic impact, and business achievements. Less than a year later, QwikBoost was first introduced at the International Air Conditioning, Heating, and Refrigeration Exposition in San Francisco, California.

Mainstream Engineering believes that the additive also could be used for industrial and commercial medium-temperature refrigeration, such as supermarket refrigerated cases. This market is very significant in that refrigeration represents more than half the energy consumed by the U.S. food sales sector. For example, the U.S. food sales sector in 1995 consumed about 71 trillion British thermal units (Btus) of energy for refrigeration out of its total consumption of 137 trillion Btus. According to these numbers, refrigeration accounted for roughly 52 percent of the total energy consumed by this sector.

■ For more information, contact Larry Grzyll via telephone at (407) 631-3550 or via E-mail at lrg@mainstream-engr.com. You can also visit Mainstream’s Web sites at <http://www.mainstream-engr.com> and <http://www.qwik.com>.



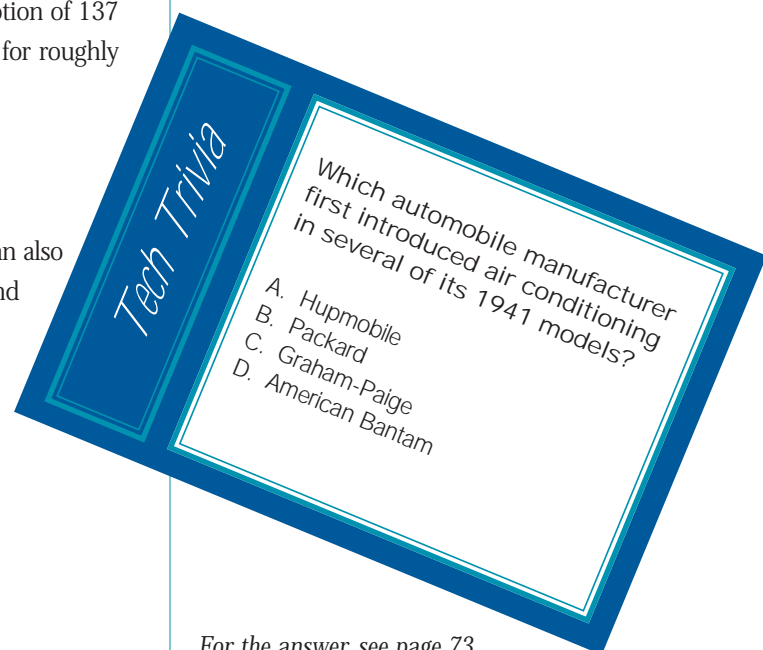
What Does It Mean to You?

QwikBoost will help automotive air conditioners cool the interior faster and produce more cool air, enabling occupants to beat the heat on hot summer days.



What Does It Mean to Our Nation?

QwikBoost can help boost the performance of the Nation’s industrial and commercial refrigeration equipment, which plays a critical role in preserving food and storing medical supplies.



For the answer, see page 73.

ULTRAFAST SWITCH ENERGIZES DIVERSE MARKETS

An ultrafast optical switching technology finds its way into sensor, medical, manufacturing, electrical utility, and scientific instrumentation markets.



■ The silicon switch (pictured above), developed by Energy Compression Research, can be used in medical, manufacturing, and electrical utility applications.

For more than 30 years, electronic switches have quietly toiled in the fields of electronics, electro-optics, and photonics. Now, optical switches are shaking up the peace.

With the introduction of more sophisticated devices, it generally has become more difficult to perform switching functions electronically. Optically, however, things get easier. Optical switches have faster response times than electronic switches and are less susceptible to electromagnetic interference, making them attractive for a wide range of commercial applications.

Energy Compression Research Corporation (ECR; San Diego, CA) has introduced an optical switching technology, called light-activated silicon switching (LASS), that offers an ultrafast alternative to electronic switches. With picosecond switching speeds and compact packaging, LASS switches have enabled a wide range of high-end commercial products for electronics, electro-optics, and photonics applications. The switches can be used to power lasers, route signals in fiber-optic communications devices, control industrial motors, and power high-frequency radar communications. LASS technology offers high efficiency and cost savings in these areas.

Light switching. LASS technology is based on semiconductor devices that use laser light to switch current on and off. A LASS device uses the absorption of laser light to create the conducting electrons within the semiconductor, resulting in a switching speed that is orders of magnitude faster than conventional electronic switches. ECR developed LASS photoconductive switches with support from Phase I and II BMDO SBIR contracts. These switches were originally designed for BMDO applications in pulsed radar, pulsed power for accelerators, and electromagnetic weaponry.

After the U.S. Department of Defense declassified LASS patents, ECR immediately began an aggressive plan to develop and commercialize LASS technology. On the basis of a market study to identify specific customer needs, which revealed an emerging market for ultrafast optical switches, the company developed LASS-based products and established a manufacturing capability. ECR introduced its first products, the ECR Pockels cell drivers, in January 1995 and completed over \$274,000 in product sales during the year. LASS-based technology is now nearing the million dollar mark in total product sales.

With the maturation of LASS, the company has transitioned its business focus from defense to commercial markets. "During our strategic work for the defense industry, we developed a large body of proprietary knowledge on how to 'marry' semiconductors and photoconductive switches to achieve previously unachievable performance in terms of speed and power," says Andrew Palowich, ECR's chief executive officer and president. "Knowing how to manufacture and integrate photoconductors with numerous associated electro-optic devices has enabled us to find much broader commercial markets."

Versatile tools. LASS's high-speed switching capabilities can boost the performance of a wide variety of products and applications, including robotic vision systems that enhance quality control in manufacturing. In addition, LASS-based light detection and ranging equipment can be used for high-accuracy proximity measurements based on reflectance. For instance, this reflectance method is used to measure the distance from the earth to communications and global positioning satellites. For biotechnology tasks, compact microlasers can be incorporated into fluorescence lifetime sensors and flow cytometers, saving space and improving instrument accuracy.

Medical applications abound for ECR's technology. LASS can be incorporated into high-repetition-rate medical lasers, such as those used in refractive eye surgery. It helps provide ultrashort pulse times with low jitter and high accuracy to reduce collateral damage to the eye. LASS also could be used in optical diffuse tomography (ODT), which uses non-ionizing laser light to create anatomical images. Although ODT is still in its infancy, researchers hope it can become a supplement to mammography, much in the way ultrasound fills that role today.

The electrical power industry is keeping its eye on LASS technology, too. In a recent study funded by the Electric Power Research Institute, ECR demonstrated in fault applications the ability to shunt a surge of 10,000 amps in 2 microseconds—five times faster than the thyristors used for this purpose. Currently, ECR is designing LASS surge-suppressing thyristors for high-power electric utility grids. Commercial devices should be available in 1999.

ECR is busy expanding its product line and currently offers Q-switched picosecond microlasers, solid-state laser-diode drivers, and fast Pockels cells. The company sells products and provides research and development services directly throughout the United States, and through eight distributors internationally. Major customers include AT&T, Toshiba, and Boeing.

■ For more information, contact David Giorgi via telephone at (619) 450-6612 or via E-mail at ecrcorp@aol.com.



What Does It Mean to You?

Light-activated switches are versatile tools that can be used to increase the accuracy of lasers for eye surgery and boost the performance of industrial vision systems for quality control.



What Does It Mean to Our Nation?

LASS technologies can benefit utilities by helping to ensure reliable power grids to light up U.S. homes and businesses.

Tech Trivia

The human brain packs enough power (electricity) to do which of the following?

- A. Give a mild shock to your finger
- B. Heat an 8-ounce cup of coffee
- C. Light a 15-watt light bulb
- D. Short-circuit your hard drive

For the answer, see page 73.



HEALTH AND MEDICAL TECHNOLOGIES

Think of BMDO technology transfer the next time you

- Read a newspaper article about someone who is surviving breast or prostate cancer.
- Get word that a friend has sustained a disabling back injury.
- Hear of a hospital patient who is being treated for throat cancer.
- View a television program featuring a medical research facility where cutting-edge techniques and technologies are being developed.



MICROWAVES ZERO IN ON BREAST TUMORS

Microwave technology produces safe and controlled deep heat to treat patients with breast cancer, prostate cancer, and other life-threatening diseases.



■ The Celsion breast cancer treatment system (pictured above) can increase the effectiveness of breast-conserving cancer treatments, such as lumpectomy, radiation therapy, and chemotherapy.



■ Celsion's deep cancer treatment system (pictured above), currently being developed, will target generally inoperable tumors deep within the body.

This year, the American Cancer Society estimates that 178,000 American women will be diagnosed with breast cancer and roughly 43,000 will die from the disease. Many of these lives may someday be saved by treating the tumor with heat, a technique better known as hyperthermia. But in targeting tumors deep inside the body, conventional heat treatments can create hot spots that burn the skin or surrounding healthy tissue.

Fortunately, Celsion Corporation (Columbia, MD), formerly Cheung Laboratories, has found a way to solve this problem. The company has developed a breast cancer treatment system, called Microfocus 1000™, that uses deep, focused heat to eradicate cancerous tumors—without overheating surrounding tissue. Concurrently heating and applying either radiation or chemotherapy shrinks tumors up to twice as fast as subjecting them only to conventional treatments.

Furthermore, recent preclinical tests conducted by Massachusetts General Hospital in Boston showed that heat alone can eradicate tumors effectively. This approach could eventually eliminate the need for radiation-based treatments, which can cause nausea, radiation burns, hair loss, and even secondary tumors. Later this year, Celsion plans to use this method to eradicate breast tumors in patients at several hospitals.

Cancel out radiation. Adaptive phased array (APA) software is key to the precision of Microfocus 1000. APA algorithms were initially developed by MIT Lincoln Laboratory (Lexington, MA) to locate airborne vehicles, such as cruise missiles, from BMDO space-based radar platforms. The algorithms were designed to overcome enemy jamming by removing the electronic noise from the radiation signals coming back to the radar. Since then, the same APA techniques have been applied in tumor eradication. In this application, they cancel out the radiation signals hitting healthy tissue, allowing the microwaves to be more precisely focused on the tumor.

APA technology gives doctors a new level of control in the heat treatment of tumors. "Hyperthermia systems have been around for a long time and, for the most part, they have been ineffective in reaching the tumor site with concentrated microwaves," says John Mon, Celsion's general manager. "APA technology focuses microwaves right on the tumor, killing the cancer cells more directly.

Because of its greater precision, it doesn't produce hot spots on surrounding tissue, so the patient feels no pain during or after the procedure."

Celsion is making significant progress in bringing Microfocus 1000 technology to the market. In September 1997, the company received premarket approval from the U.S. Food and Drug Administration to incorporate APA technology into its already-approved Microfocus 1000, making the device immediately available for medical use. Celsion also has obtained an exclusive license for the commercial use of MIT's APA technology. Several hospitals have successfully used Celsion's prototypes in animal models, paving the way for the treatment of human patients.

Intravenous drug delivery. In a sponsored research alliance with Duke University Medical Center in Durham, North Carolina, Celsion will use APA technology to develop a new family of heat-activated targeted drug delivery, gene therapy, and anti-angiogenesis systems. The first major emphasis of the alliance is the development of heat-sensitive lipid-based microcarriers, which encapsulate drugs for intravenous delivery. Upon reaching the tumor where the focused heat is applied, the microcarrier is designed to undergo a physical change that leads to a release of the entire encapsulated drug content within a few minutes. This approach concentrates the toxic effects of the drug at the site by 50 times that of current liposome therapies, with minimal side effects.

Celsion is also developing APA-based devices for treating prostate cancer and other life-threatening diseases. The APA prostate cancer treatment system will increase the effectiveness of radiation therapy by about a factor of two without any added side effects. Preclinical testing is currently being conducted in Celsion's laboratory with a prototype. This year, Celsion will ship the prototype to the University of California at San Francisco where preclinical studies using animals without tumors will be conducted.

A deep cancer treatment system also uses the focused-heating APA method, safely eradicating tumors far inside the body without harming surrounding tissue. The system is designed to target tumors in the liver, rectum, cervix, pancreas, lung, and other areas deep within the torso. The prototype, which is currently being developed, will be used in clinical trials at both Duke University Medical Center and Northwestern Memorial Hospital in Chicago, Illinois.

■ For more information, contact John Mon via telephone at (410) 290-5390 or via E-mail at celsion@aol.com. You can also visit Celsion's Web site at <http://www.celsion.com>.



What Does It Mean to You?

Celsion's new technology offers more accurate delivery of thermal therapy for eradicating cancerous breast tumors, helping to widen the range of treatment choices for women with these disorders.



What Does It Mean to Our Nation?

Celsion's Microfocus 1000 can be used as part of the thousands of breast-conserving surgeries that are performed each year, reducing the complications and risks associated with these procedures.

Tech Trivia

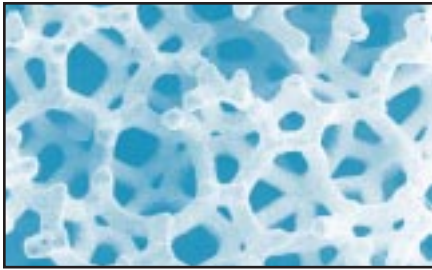
Out of every ten breast growths, how many are noncancerous?

- A. Six
- B. Seven
- C. Eight
- D. Nine

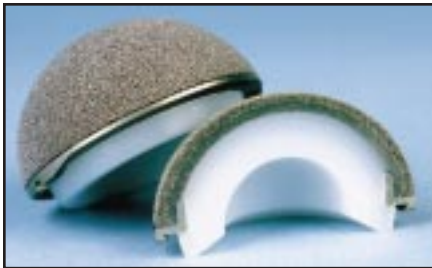
For the answer, see page 73.

IMPLANTS MEAN MORE SUPPORT FOR WEAKENED SPINES

A synthetic cellular material once used to insulate rocket nozzles is now restoring mobility and comfort to the lives of spinal implant patients.



■ Hedrocel® cellular materials (pictured above) are readily compatible with natural bone.



■ Pictured above is the Hedrocel® Acetabular Cup, a commercially available device used in total hip replacements for patients suffering from hip arthritis.

The human spine may be resilient, but it is not impervious to harm. Damage can result from trauma when the tissues between the vertebrae of the spine are compressed, which is what happened to actor Christopher Reeve during his tragic horseback riding accident. Less obvious damage can result from bone diseases such as osteoporosis and arthritis, which gradually destroy spinal bone mass during the aging process.

Ultramet, Inc. (Pacoima, CA), has developed a synthetic cellular biomaterial that in some cases of trauma and disease could help shore up the spine, preventing further injury. With its relatively high strength and porous structure, the biomaterial can act as a biocompatible replacement for damaged vertebral bodies and as a facilitator for spine fusion. In either case, it can greatly reduce the pain typically associated with bone and between-the-bone tissue loss, thus improving the quality of life for those with debilitating spinal problems caused by accidents or bone degeneration diseases.

Similar to cork. The biomaterial is an open-celled lattice that mimics the properties of, and is compatible with, bone. It appears similar in structure to natural materials such as coral and cork, but it is made stronger with tantalum—the most corrosion-resistant, biologically acceptable metal available today. The biomaterial was derived from a BMDO SBIR project to develop synthetic cellular foams that could serve both as insulators and kinetic energy absorbers. BMDO funded the materials development to produce insulation technology for components inside rocket nozzles.

Implex Corporation (Allendale, NJ) has licensed and further developed this biomaterial for use in many musculoskeletal applications, including the human spine. Called Hedrocel®, the biomaterial can be used for permanent spinal applications. For example, it can be implanted between two vertebrae, providing immediate structural support for the spinal column. Left alone, it allows bone from the vertebrae above and below to gradually infiltrate its pores. This bone will gradually join and form a true bony fusion across the whole joint. This fusion reduces the possibility of pain from compressed spinal nerves.

The company considers Hedrocel to be a platform technology whose porosity and flexibility are well suited for spinal and other human body applications.

"The biomaterial's uniquely shaped, interconnecting pores result in a bulk volume porosity of greater than 80 percent," says Robert Cohen, Implex Corporation's vice president of product development. "Because of this high porosity, it has more room for bone to grow into the material, providing greater biological stability than conventional implant materials." Mr. Cohen adds that the material's flexibility "more closely resembles that of bone." Any spinal replacement material that is too stiff could cause undue load transmission to the spine because of the difference in flexibility characteristics. The bone will then remodel abnormally, creating another surgical challenge in the future.

Hedrocel implants can help patients with conditions such as osteoporosis when doctors feel that structural support is the most preferable option. According to the National Osteoporosis Foundation, osteoporosis is a major public health threat for more than 28 million Americans, 80 percent of whom are women. In the United States today, 10 million individuals already have the disease and 18 million more have low bone mass, placing them at increased risk for osteoporosis. The estimated national direct expenditures (hospitals and nursing homes) for osteoporotic and associated fractures is \$13.8 billion (\$38 million each day), and the cost is rising.

Successful trials. Implex's Hedrocel vertebral body replacement implants have been successfully used in 12 patients in Europe. Some patients had a lumbar (lower back) bone replaced, while others had a cervical (neck) bone replaced. In Europe and the United States, the Hedrocel cervical spacer implants have also successfully been used for cervical fusion by replacing the disc to allow the adjacent bones to grow together. Implex reports that the clinical results to date are positive and compelling.

Other Hedrocel products for joint replacement and fusion are emerging. In mid-1997, the company received U.S. Food and Drug Administration acceptance for a Hedrocel socket-side hip implant, which can be used in total replacements for patients with hip arthritis. These implants are currently being marketed. In addition, Implex is investigating the use of Hedrocel in cases requiring the fusion of joints in the human body; typically this procedure gives the patient a better quality of life after an accident or condition that makes bending a finger, wrist, or ankle too painful.

■ For more information, contact Robert Cohen via telephone at (201) 818-1800 or via E-mail at robert.cohen@implex.com.



What Does It Mean to You?

Spinal implants can help relieve pain in persons suffering from degenerative spinal disease and may soon help restore motion to arthritic ball-and-socket joints in the hips.



What Does It Mean to Our Nation?

Spinal implants can help improve the quality of life for the 25 million Americans who either have or are at high risk for osteoporosis, which results in annual estimated costs of more than \$10 billion for direct medical treatment.

Tech Trivia

About how many vertebral fractures does osteoporosis lead to annually?

- A. 2,500
- B. 5,000
- C. 50,000
- D. 500,000

For the answer, see page 73.

OPTICAL BIOPSY SHINES NEW LIGHT ON CANCER

A new laser-based biopsy procedure can diagnose cancer of the esophagus almost instantaneously without the pain of tissue sampling.



■ Instead of using a pincer-tipped cable (pictured in foreground), researchers have developed a new, laser-based, nonsurgical method to diagnose certain cancers, such as esophageal cancer.

It was 18 years ago that retired engineer Melvin Francis first noticed something was wrong. “I had burning sensations in my throat,” he recalls. With the aid of an endoscope, Dr. Bergein Overholt diagnosed the problem as Barrett’s esophagus, a precancerous condition in which the lining of the esophagus is severely irritated.

After the surgery to remove the precancerous abnormalities, Dr. Overholt began a series of biopsies to analyze the tissue in Francis’ esophagus. These procedures removed samples of sensitive esophageal lining and were quite painful, according to Francis. And obtaining the results took days, producing many anxious moments for him and his family. This scenario is typical for many others diagnosed with esophageal cancer.

Working with Dr. Overholt and research scientist Dr. Masoud Panjehpour, Dr. Tuan Vo-Dinh of Oak Ridge National Laboratory (ORNL; Oak Ridge, TN) has developed a new, fast, noninvasive fiber-optic probe to detect cancer of the esophagus. The probe induces and detects fluorescence of the tissue and can determine whether or not suspicious lesions are cancerous. It yields diagnoses noninvasively, without biting into tissue the way a conventional biopsy does. And it produces diagnoses fast, without the delay of sending away samples for evaluation and waiting for a pathologist’s report.

Tissue’s glow analyzed. The probe substitutes light for the scalpel of surgical biopsy. Using the body’s own light emission in reaction to certain wavelengths of laser light, a spectrometer, an instrument for visualizing light emitted from an organ’s tissue, can detect unique fluorescent signals. As demonstrated in studies conducted by the probe’s developers, this activity can reveal cancerous hot spots without removing tissue. Dr. Vo-Dinh first realized the potential of this technology while using lasers to conduct data storage experiments for BMDO and environmental monitoring studies for the Department of Energy. BMDO’s experiments focused on a new technology for optically storing vast amounts of computer data, called surface-enhanced Raman optical data storage.

The optical probe technology could change the course of medicine in diagnosing certain tumors. “Optical biopsies are noninvasive and fast because no tissue is removed and the diagnosis can be made almost immediately,” says Dr. Vo-Dinh, ORNL’s division leader for the Life Sciences Group. “Conventional tumor

biopsy requires the use of a pincer-tipped cable to physically remove tissue for analysis. Such a procedure entails recovery time for patients and an expensive, time-consuming laboratory analysis to determine malignancy.”

In the new method, instead of the biopsy “pincer” cable, a fiber-optic cable is inserted in the biopsy channel of an endoscope. Laser light is directed through the cable’s optical fibers onto the tissue. The tissue absorbs the laser light and, depending on the light’s wavelength, re-emits it as a fluorescent “glow,” which is spectrally analyzed. Using a special data analysis method, the researchers discovered that the spectral “fingerprint” of a malignant tumor can be distinguished from that of a noncancerous tumor.

Highly accurate. The probe technology was put to the test against standard mechanical biopsies at the Thompson Cancer Survival Center in Knoxville, Tennessee. In a research investigation involving 100 patients, the technology accurately diagnosed 98 percent of all esophageal tumors. In fact, in one case, the mechanical biopsy was normal, but the optical biopsy detected a malignancy.

The technology has been licensed to Venture Alliance (Knoxville, TN), a venture development company that invests in and manages early-stage technologies, particularly those for the medical industry. Venture Alliance formed Optical Biopsy Technologies, L.L.C., to further develop and commercialize the optical probe technology. Working with the U.S. Food and Drug Administration, Optical Biopsy Technologies has completed pilot clinical studies for both gastrointestinal (GI) and cervical applications and has received an investigational device exemption for the GI application. The company is currently seeking additional investors.

Vo-Dinh’s BMDO-funded research and development in optical data storage also led to the development of a surface-enhanced Raman gene probe (SERGen). The probe requires no radioactive tags or special fluorescing dyes and cuts gene identification time drastically, from as many as 16 hours to a matter of minutes. Because of its speed and sensitivity, the probe could prove useful in many areas.

For example, in our era of increasing antibiotic resistance, SERGen may prove a boon to doctors who want to quickly identify resistant organisms. Doctors can then prescribe the proper medication and avoid a wasted course of ineffective antibiotics. SERGen also could offer a drastic improvement in the methodology used for gene sequencing and identification, such as that being applied in the Human Genome Project.

■ For more information, contact Dr. Tuan Vo-Dinh of ORNL via telephone at (423) 574-6249 or via E-mail at tvo@ornl.gov. You can also visit ORNL’s Web site at <http://www.ornl.gov>. Or, contact Robert Lundgren of Venture Alliance via telephone at (423) 523-2346 or via E-mail at lundgren@venturealliance.com.



What Does It Mean to You?

Optical biopsy can help to diagnose cancers earlier and before they have had a chance to spread, and can also alert the clinician to precancerous conditions that can thereafter be carefully monitored.



What Does It Mean to Our Nation?

Optical biopsy is an emerging technique that can be performed at a cost 10 times cheaper than conventional biopsies, reducing the cost of specialized medical care for cancer patients.

Tech Trivia

- Which of the following does not describe Chandrasekhara Venkata Raman, who discovered Raman spectroscopy?
- A. A Nobel Prize winner
 - B. An assistant accountant
 - C. A British knight
 - D. A famous tiger hunter

For the answer, see page 73.

A NEW DAY DAWNS FOR REVITALIZED LASER

Once limited to the physics laboratory, the free-electron laser has found a new life as a unique tool for medical and industrial research.



■ A laser technician works on Vanderbilt University's free-electron laser (pictured above), which has provided major breakthroughs in mammography and neurosurgery.

In the early years of medical laser research, doctors used single-wavelength lasers with limited dynamic properties. When the free-electron laser (FEL) was developed, it offered short pulses, high peak power, and a greater range of wavelengths. Not surprisingly, this innovation yielded a host of advances in the medical field. Vanderbilt University (Nashville, TN) is a nexus of these advances.

During the late 1980s, Vanderbilt was one of several centers of excellence to receive funding through BMDO's Medical Free-Electron Laser (MFEL) program. The U.S. Congress conceived the MFEL program as a means to leverage and transfer technology from the military's laser research program to the medical community. Since then, the advanced capabilities of the FEL have benefited both clinicians and basic scientists, enabling dramatic progress in laser medicine, materials science, and a host of other specialties. Many research centers translated the FEL's advances into procedures that now use portable lasers such as the neodymium:YAG.

Underground vault. Vanderbilt, however, has taken a novel approach, building a multidisciplinary facility around its 75-foot-long FEL. Housed in the basement of the W.M. Keck Free-Electron Laser Center, the enormous laser is encased in a 13,000 ft² vault of thick concrete. A series of tubes and mirrors route the beam to the second floor of the center, which houses the FEL control room, five laser target rooms, two experimental surgical suites, and supporting biology and electronics laboratories. The arrangement encourages a free exchange of ideas among surgeons, clinicians, physicists, and biologists who are the primary beneficiaries of the FEL's presence.

The FEL program at Vanderbilt won an initial grant from the Office of Naval Research (ONR) and BMDO (then the Strategic Defense Initiative Organization) in 1987. The W.M. Keck Foundation contributed funds in 1993 to help expand the FEL facility, and ONR added more funding in 1996. Today, Vanderbilt scientists are testing the laser for a variety of clinical purposes.

For example, one primary task is generating monochromatic x-rays for mammography. According to breast cancer specialist Dr. Frank Carroll, these FEL-generated beams potentially will make tumor images "stand out like headlights," greatly enhancing a mammographer's ability to detect cancer. In addi-

tion to better image clarity, this method exposes the patient to ten times less radiation than conventional mammography. In the future, work with Los Alamos, Lawrence Livermore, and Oak Ridge National Laboratories is expected to yield a new imaging technique that uses 100 times less radiation than current x-ray technology.

Tumors beware! Vanderbilt neurosurgeon Dr. Michael Copeland says that the FEL is the best answer yet for expanding the role of lasers in neurosurgery. Carbon dioxide and erbium:YAG lasers cause too much thermal damage to be used extensively in neurosurgery, but the more precise control and tunability of the FEL may change the way surgeons regard lasers for this specialty. Deep-seated tumors previously considered inoperable may be treated more effectively with the infrared beams of the FEL. Pending approval by the U.S. Food and Drug Administration by the end of 1998, Dr. Copeland expects to perform the first human neurosurgery using the FEL.

In addition to laser medicine, the FEL can open windows into the materials world of such manmade structures as solar cells, electronic devices, and biosensors. Amorphous silicon solar cells can be bombarded with intense light to examine how and why these cells wear out over time. In the same way that the FEL interacts with the individual atoms of DNA to give molecular information, the atoms in a semiconductor can be manipulated to yield information about its electrical properties. Even the interface between living and nonliving structures can be explored to create biosensors, which are implanted silicon chips that can react to glucose, for instance, and deliver insulin in response.

In electronics, diamond substrates are another interesting topic for FEL users. For many years, researchers have worked to harness the excellent properties of diamond to make faster transistors. A problem with modifying diamond surfaces, however, is the destructive thermal heating associated with conventional processing methods. The FEL's precise tuning, short pulses, and high power can help scientists cut through diamond without collateral heat damage and without disrupting the orderly crystalline lattice that makes diamond so desirable.

The FEL's potential ultimately will be fulfilled not by the nature of the technology, but rather by the vision of those who use it. By cooperating and exploring new ideas, Vanderbilt's FEL researchers will likely produce even more exciting developments in the future.

■ For more information, contact Dr. Glenn S. Edwards via telephone at (615) 343-6146 or via E-mail at edwardg1@ctrvax.vanderbilt.edu. You can also visit Vanderbilt's Web site at <http://www.vanderbilt.edu>.



What Does It Mean to You?

Free-electron lasers may allow surgeons to cut with far less damage to surrounding tissue and mammographers to obtain the clearest images to detect cancer, leading to better health care procedures.



What Does It Mean to Our Nation?

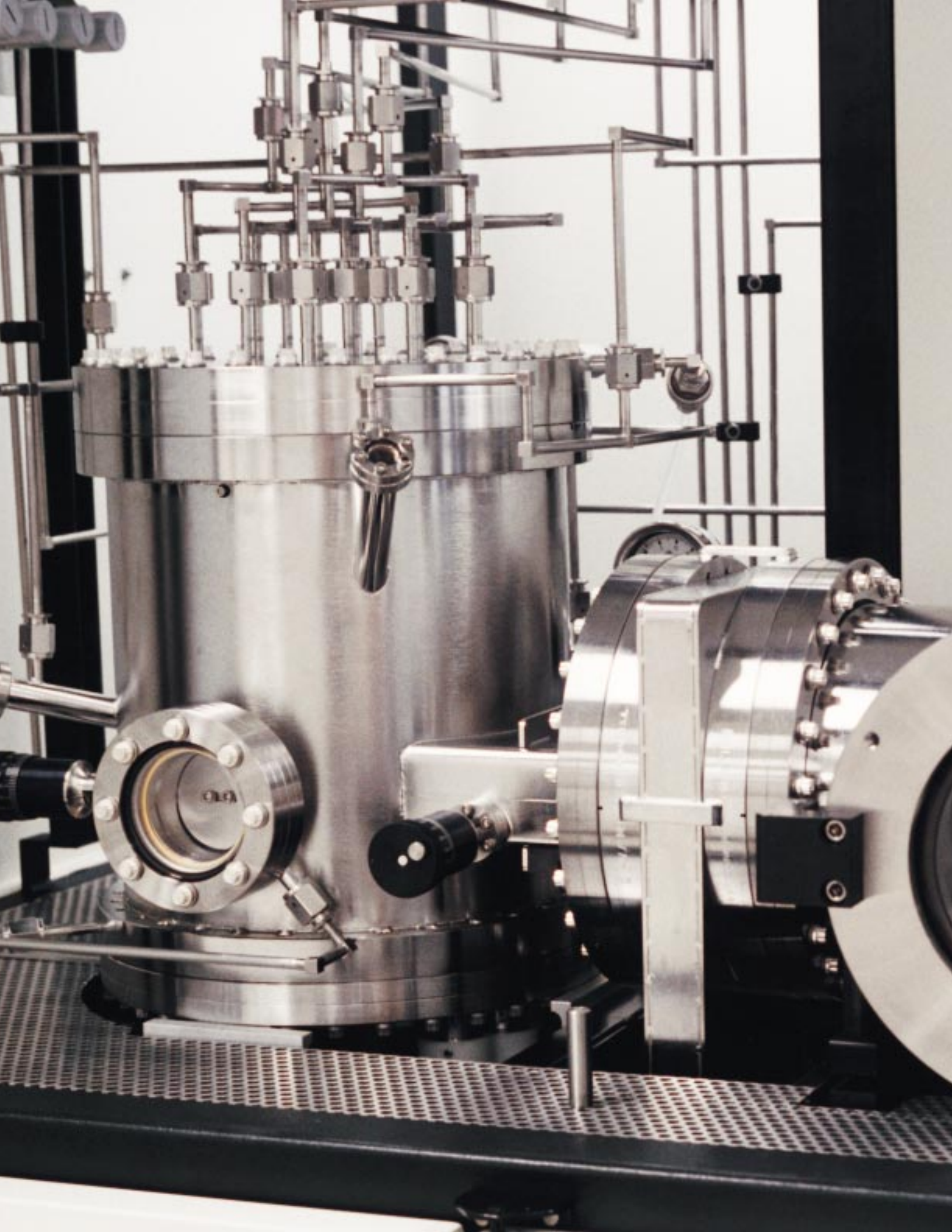
Free-electron lasers can address the challenges of human disease and disorders through new treatment techniques, potentially improving patient care and reducing medical costs.

Tech Trivia

By using the properties of electrons, scientists have been able to do all of the following except what?

- A. Magnify the smallest objects
- B. Observe distant galaxies
- C. Prove the Big Bang theory
- D. Investigate atomic structures

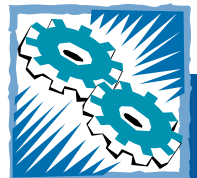
For the answer, see page 73.



MANUFACTURING TECHNOLOGIES

Think of BMDO technology
transfer the next time you

- Choose the micro-processor speed of your new computer.
- Open a bottle of aspirin.
- Purchase an electronic pager or mobile phone.
- Hear the roar of a jet engine when an airplane takes off.



WAFER MAKER PUSHES THE SPEED LIMIT

A low-cost, high-speed tool enables large-scale production of compound semiconductor-based devices for photonic and electronic applications.



■ EMCORE has developed a high-volume nitride deposition tool that combines multiwafer capabilities and patented TurboDisc™ metal-organic chemical vapor deposition technology (pictured above).

Compound semiconductor materials are attractive for new electronic devices because, unlike silicon, they can be tailored for optical and high-frequency applications. Typically, electronics manufacturers have met the needs of research and pilot production of compound semiconductor layers with in-house systems and technologies. However, producing commercial volumes of starting material often exceeds the capabilities of in-house solutions.

EMCORE Corporation (Somerset, NJ) has developed a process technology called TurboDisc™ that is key to the low-cost, high-volume production of compound semiconductors. This technology not only ensures uniformity of deposition across the wafer to produce better yields, it also allows users to scale easily from research to commercial volumes with substantially reduced time and effort. TurboDisc tools can prepare compound semiconductor wafers from 2 inches to 14 inches in diameter in a variety of material combinations.

EMCORE's technology uses a unique high-speed rotating disk in a stainless-steel growth chamber to decompose reactive gases and deposit ultrathin layers of materials (metals, conductors, oxides) on a substrate wafer. Layers grown by TurboDisc deposition allow for the design of circuits and devices that are faster and denser, have photonic capabilities, and possess properties superior to those manufactured using traditional techniques. BMDO's SBIR program funded early work at EMCORE to optimize the TurboDisc system for gallium arsenide film growth and subsequently funded EMCORE's initial research in large area growth of compound semiconductors, most notably gallium nitride.

Low-cost volume production. TurboDisc makes possible cost-effective metal-organic chemical vapor deposition (MOCVD) production systems for producing commercial volumes of high-performance compound semiconductor wafers and devices. "This technology addresses the critical need of electronics manufacturers to cost-effectively get to the market faster with higher volumes of new and improved high-performance products," says Dr. Ian Ferguson, EMCORE's director of contract research. "It's an important breakthrough that transitions MOCVD technology out of the laboratory into the production environment."

TurboDisc technology has enabled EMCORE to become the leading manufacturer of production systems used to fabricate compound semiconductor wafers.

In fiscal year 1997, a majority of the company's \$47.8 million in revenues resulted from TurboDisc technology. In March of that year, EMCORE announced an initial public offering of 2.5 million shares of its common stock at \$9 per share. The company raised over \$20 million in proceeds, most of which will be used to expand its manufacturing facility.

TurboDisc systems are being used by some of the world's leading semiconductor companies, including Siemens, Hewlett-Packard, and Samsung. These systems come in a variety of platforms: Enterprise for volume production, Discovery for pilot production, and Explorer for research. EMCORE also offers customers the Epimetric *in situ* photoreflectance system to monitor the growth rate and thickness uniformity of a broad range of materials.

Bright blues. EMCORE's commercialization of BMDO-funded research and development has aided the development of commercial ventures in gallium nitride (GaN). The company recently introduced SpectraBlue, a TurboDisc designed specifically for the production of layers for very bright blue light-emitting diodes (LEDs) and blue lasers. In addition, it recently has entered a joint venture with the newly formed Uniroyal Optoelectronics Division of Uniroyal Technology Corporation to produce high-brightness LED epitaxial wafers, lamps, and display devices. The initial focus of the venture will be on the manufacture of GaN devices.

EMCORE's expansion into wafer and package-ready device production has been spurred almost entirely by requests from customers whose wafer needs exceed their available in-house production capabilities. For example, the company has formed a strategic relationship with General Motors Corporation to develop and manufacture magnetoresistive sensor products for use in automotive applications. It has also been involved in the development of solar cell technologies for telecommunications satellites and transmitter and display technologies for wireless communications applications.

The support EMCORE received under the BMDO SBIR program has helped motivate the company to achieve landmark results, which have recently been acknowledged by the U.S. Small Business Administration (SBA) and New Jersey Technology Council (NJTC). This year, the SBA presented EMCORE with its Tibbetts Award for superior SBIR technological innovation, economic impact, and business achievements. NJTC selected EMCORE as its Product Development Company of the Year for 1998.

■ For more information, contact Dr. Ian Ferguson via telephone at (732) 271-9090, ext. 4114, or via E-mail at ianf@emcore.com. You can also visit EMCORE's Web site at <http://www.emcore.com>.



What Does It Mean to You?

Because TurboDisc systems can reduce manufacturing costs and increase production rates for compound semiconductor devices, they will allow more affordable cellular telephones, pagers, flat-panel displays, and electronic automotive components.



What Does It Mean to Our Nation?

TurboDisc systems are helping U.S. electronics and optoelectronics manufacturers, such as AT&T, Honeywell, and Uniroyal, to cost-effectively get to market faster with high volumes of new and improved high-performance products.

Tech Trivia

The first commercially usable LEDs were developed in the 1960s by combining gallium, arsenic, and what other material to obtain a 655-nanometer red light source?

- A. aluminum
- B. indium
- C. antimony
- D. phosphorus

For the answer, see page 74.

TUNABLE FILTER SOLVES PROCESS PROBLEMS

Acousto-optic tunable filters create near-infrared instrumentation that speeds up real-time process control and analysis for a broad range of industries.



■ A near-infrared spectrometer developed at Brimrose ensures that the right pills and powders (pictured above) are in the right vials for the pharmaceutical industry.

Near-infrared (NIR) spectroscopy is ideal for keeping industry under control. NIR spectrometers will allow manufacturers to analyze industrial process problems. But mechanical-based versions have speed and reliability limitations that greatly reduce their effectiveness and survivability on the production line.

Brimrose Corporation of America (Baltimore, MD) has developed acousto-optic tunable filter (AOTF) technology that makes NIR spectroscopy a faster, more reliable tool for monitoring industrial processes. The company's all solid-state tunable filters eliminate the need for moving parts, such as rotating gratings and mirrors, to scan the NIR spectrum. This improvement not only enhances the system's reliability, but also increases its speed. While grating or mirror-based systems could scan a range of interest only once per second, Brimrose's AOTF technology can scan the same area more than 30 times faster.

Ultrasonic waves. An AOTF is a compact optical device that uses ultrasonic waves to alter the index of refraction of an optical crystalline medium. The device can obtain data in the NIR with a high degree of wavelength resolution in practically real time. Also, because the AOTF technology is all solid-state, it is rugged and has a long lifetime. In addition, the system is pre-aligned so it does not require lengthy alignment upon replacement. BMDO originally funded Brimrose's research in acousto-optics for use in optical communications, optical computers, and guidance and surveillance systems.

AOTF technology is key to successful NIR spectroscopy. "The slow data acquisition of traditional NIR instruments has been a major drawback to their commercial use in real time, closed-loop monitoring and control of industrial processes," says Dr. Gabriel Levin, Brimrose's director of applications development. "However, being able to quickly tune from one wavelength to another, AOTF technology provides rapid results. Combined with inexpensive microprocessors and powerful software, it can greatly benefit production-line technology."

Brimrose's AOTFs, which are able to analyze roughly 25 pills per second while the pills are on the conveyor belt, can be used for quality control in the pharmaceutical industry. In this way, manufacturers can ensure that the correct pills are going into the correct vials. Processing improvements are expected to increase the AOTF's capability to 100 pills per second. In either case, the sys-

tem's performance compares well to other spectrometers, which at best can read two tablets per second. In a slightly different application in the same industry, AOTFs can be used to ensure that mixtures of pharmaceutical powders are blended uniformly and that solvents are recovered efficiently.

AOTF technology also can be used to monitor the properties of petrochemicals to ensure their quality. For example, it can be used to monitor kerosene's flash-point, which is the temperature at which kerosene can self-ignite and is related to the chemical features of the substance. It is used to automatically control the proper blending of gasoline mixtures to create the desired octane number. AOTFs have also been used to verify the proper mix of bleach for a bleach manufacturer, allowing the manufacturer to optimize the amount of water that can be used, thereby realizing savings in chemical costs. The manufacturer had previously used too much chemical intentionally to ensure that the bleach would meet minimum specifications.

The AOTF holds promise for many other production-line applications. It may be used on an assembly line to ensure quality production of ceramic cores for turbine blades. It also can help monitor the casting of large aluminum parts for automobiles. For consumer products, the AOTF has monitored the thickness of plastic film as the film is running on the rollers and has detected lack of uniformity in the material. In food applications, it has monitored the moisture content of herbs and spices before final grinding and checked orange juice quality. And in dairy plants, the spectrometer has been used to control production of butter, buttermilk, cream, and processed cheese.

Pill inspection. Brimrose has found widespread commercial success marketing its technology to the pharmaceutical industry. The company has sold more than 60 systems in this area. These systems are being used by some of the world's leading pharmaceutical companies, including Pfizer, Merck & Company, SmithKline Beecham, Hoffmann-La Roche, Ortho-McNeil, and Eli Lilly and Company. In some cases, the systems are used for quality control in solvent recovery and bulk powder inspection. They are also used for powder blending and tablet inspection.

The company is making its presence known overseas as well. It has four wholly owned subsidiaries in Brazil, Israel, the United Kingdom, and Germany. An additional company is planned for 1999 in Israel. Brimrose also works through distributors in the international arena, such as in Scandinavia, Korea, and Japan.

■ For more information, contact Dr. Gabriel Levin via telephone at (410) 931-7200 or via E-mail at glevin@brimrose.com. You can also visit Brimrose's Web site at <http://www.brimrose.com>.



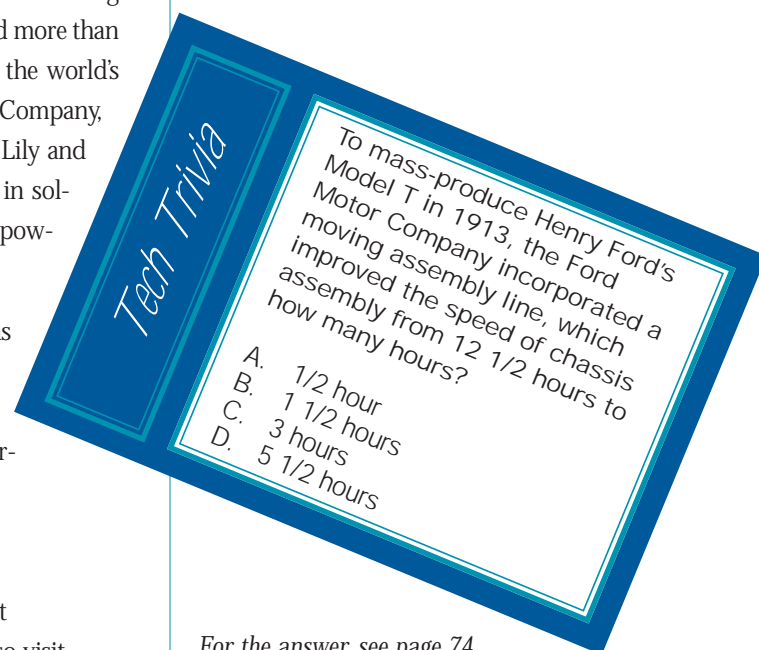
What Does It Mean to You?

Acousto-optic tunable filters will help monitor industrial processes more accurately, ensuring that pharmaceuticals are properly bottled and labels on edible products are more readable and accurate.



What Does It Mean to Our Nation?

Systems based on acousto-optic tunable filter technology will help U.S. manufacturers speed up processes, thus reducing production time while increasing quality control.



For the answer, see page 74.

NEW MACHINE SHAPES UP WAFERS BETTER

A technology once used to shape optical surfaces now produces flatter, cleaner, and smoother bulk silicon and silicon-on-insulator wafers.



■ The Precision Wafer Shaper 200 (pictured above), developed by IPEC Precision, Inc. (Bethel, CT), uses plasma-assisted chemical etching to produce ultraflat silicon wafers up to 300 millimeters in diameter.

For microchips to continue getting faster and more powerful, chip designers will need to make transistors smaller and the connecting lines between them thinner. A key lies in finer methods of imaging the circuitry on silicon wafers, a process known as lithography. Current lithographic techniques will be unable to provide the precise imaging needed for future chips, in part because silicon wafers aren't flat enough.

To better prepare for chip fabrication, manufacturers typically use grinding, etching, or polishing processes to smooth out the surface of these wafers, thus removing any microcracks or surface roughness. Unfortunately, many of these chemical and mechanical processes are difficult to control and can result in imperfect wafers.

One solution is high-precision wafer processing equipment developed by IPEC Precision, Inc. (Bethel, CT). This equipment produces smooth, uncontaminated, and undamaged bulk silicon and silicon-on-insulator wafers, and it does it with better control than conventional grinding, chemical/mechanical polishing, and wet chemical etching techniques do. Its precise shaping capability will help solve critical depth-of-focus problems in optical lithography used to fabricate advanced devices with line widths below 0.35 microns.

Controllable material removal. At the heart of IPEC Precision's wafer shaping equipment is a novel, patented process called plasma-assisted chemical etching (PACE). In PACE, a plasma-excited reactive gas chemically combines with the surface material to generate a volatile product that is pumped away, removing silicon in highly predictable and controllable quantities. Today, IPEC Precision maintains the rights to more than 30 patents covering many aspects of PACE technology.

Originally conceived and patented by the Perkin-Elmer Corporation, PACE was licensed to Hughes Danbury Optical Systems, which eventually sold the technology and its Precision Material Operations (PMO) group to IPEC. The PMO group was renamed IPEC Precision. BMDO funding helped Perkin-Elmer refine PACE technology for shaping and polishing optical mirrors used in missile tracking systems and high-powered lasers.

"Wafers need to be perfectly flat to allow exposures to be printed for the smaller features and linewidth characteristics of next-generation semiconductors," says Dr. Peter Mumola, IPEC Precision's president. "Our wafer processing equipment creates a flatter surface, which increases the precision with which photolithography can imprint multiple layers of circuit diagrams and reduces wafer defects in the production of advanced semiconductors. This technology opens up the possibility of pushing optical lithography well into the 21st century."

Clearly, PACE technology has made a financial difference in the company's bottom line. "In fiscal year 1997, sales of wafer processing equipment using PACE technology reached \$11 million," says Randy Young, IPEC Precision's marketing director. "Our goal in fiscal year 1998 was to significantly increase this figure through add-on orders from existing customers and customer base expansion." IPEC Precision's customers include virtually all of the major semiconductor manufacturers in the world who, in turn, have sold polished silicon wafers to some of the world's largest chip makers, including Intel and Motorola.

Next-generation silicon wafers. MEMC Electronic Materials, Inc. (St. Peters, MO), recently purchased \$5.4 million of IPEC Precision's machines and may buy additional tools for its worldwide semiconductor manufacturing operations. The companies agreed to implement a multiphase, two-year program to develop new tools based on PACE technology for producing future generations of silicon wafers. When the product development is complete, it is anticipated that next-generation silicon wafers will be flatter, cleaner, and smoother than any available today, and will permit MEMC's customers to produce faster, more complex semiconductor devices.

To cement the deal, IPEC and MEMC formed PlasmaSil, a limited liability company owned 60 percent by MEMC and 40 percent by IPEC Precision. PlasmaSil will own all the intellectual property developed under the cooperative development program. The goal of the company will be to license the newly developed technology to IPEC Precision and receive royalties on sales.

■ For more information, contact Randy Young via telephone at (203) 731-6700 or via E-mail at ryoung@ipec-precision.com. You can also visit IPEC Precision's Web site at <http://www.ipec.com>.



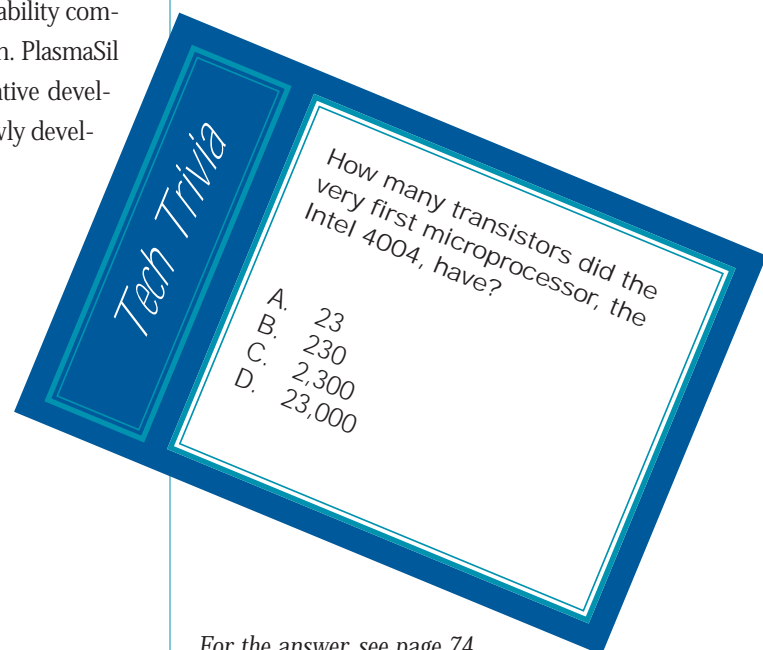
What Does It Mean to You?

New processing equipment for ultraflat silicon wafers will improve the quality and lower the cost of microchips, which have worked their way into many consumer electronics, from pagers, video games, and cellular phones to fax machines and personal computers.



What Does It Mean to Our Nation?

With major wafer suppliers using better wafer shaping equipment, chip makers such as Intel and Motorola can improve the quality of their products while reducing manufacturing costs.



For the answer, see page 74.

HIGH-ENERGY LASER BLASTS METALS

A high-energy laser system shocks metal components such as hip implants and engine fan blades, making the parts more resistant to fatigue and corrosion.



■ Lawrence Livermore technicians align the neodymium-doped glass laser (pictured above), which offers a peak power of 3 billion watts, roughly equivalent to the power output of a nuclear power plant.

Imagine using a shotgun to shoot tiny balls—as small as grains of salt—at the surface of a metal, generating a compressive stress near the surface. In essence, that is what manufacturers call peening, and they have been doing it for years to reduce metal fatigue and corrosion. In the 1980s, researchers discovered that lasers couldpeen metals with deeper penetration, increasing their resistance to failure in high-surface tension applications. But creating a commercially viable, high-energy, high-repetition-rate laser to accomplish this task has been difficult.

Lawrence Livermore National Laboratory (LLNL; Livermore, CA) has developed a powerful, fast-firing laser that could help bring this peening technology to market. The neodymium-doped glass laser features an average 600 watts of power and can fire 10 pulses per second. Previously, lasers for peening could generate only one pulse every two seconds, making the process economically unattractive. While conventional peening reaches a depth of about 1/100 of an inch to instill compressive stress, LLNL's laser can penetrate four times deeper. This increase is critical to stop stress-cracking in engine blades, rotors, and gears.

Laser zig-zag. The key to the laser's commercial viability is its slab cavity design, which features reduced thermal buildup and wavefront distortion to achieve higher repetition rates. Laser light propagates through the slab in a zig-zag pattern to minimize wavefront distortions. In addition, the laser's gain medium is thin, providing more efficient heat extraction. BMDO funded the development of the laser at LLNL for optical imaging of space objects. Other contributors include the U.S. Navy, the U.S. Air Force, the Department of Energy, and the Defense Advanced Research Projects Agency.

LLNL has licensed the laser peening process to, and has a cooperative research and development agreement with, the Metal Improvement Company (Paramus, NJ) to develop laser peening as a commercial process. Work under the initial phase of the agreement is expected to last about two years. Part of this effort includes working with companies to laser peen test components for their evaluation. Commercial products manufactured with the technology, called LasershotSM Peening, are two to four years away from introduction.

Metal Improvement, the largest U.S. supplier of peening services, says that a new laser peening system using LLNL's laser will find applications throughout

the metal working industry. "There is definitely a need for this process," says Jim Daly, Metal Improvement's senior vice president. "Laser peening won't replace conventional shot peening, but it will be used in areas where deeper depths of compressive stress are needed." In general, the "deeper the compressive stress, the better damage tolerance," adds Daly.

Strengthening airplane engine parts, such as rotors, disks, and blades, will be one of the first uses of the new laser. The U.S. Air Force sees LLNL's laser peening technology as a way to address its number one propulsion concern—high cycle blade fatigue. Early tests have shown an increase of between 10 and 40 percent in metal fatigue strength, allowing engines to operate at higher stress loads without cracking. Other aviation industry studies have shown that engine blades—which can cost \$30,000 to \$40,000 each—last three to five times longer when treated with the laser peening process.

Hardening parts. Laser peening has additional uses in aviation as well as other industries. The technology could be used to increase the resistance of jet engine blades to damage from objects such as birds, ice, or stones, which can damage the edge of a blade. Once an object strikes and damages the fan blade's edge, the flaw can propagate through the blade, leading to accelerated blade failure and possibly the destruction of an engine. Beyond aircraft, laser peening could be used to harden the surface of hip joint implants, making them more durable. Other potential applications exist within the automotive, oil tool, marine, chemical, and power generation industries.

The laser also could be applied to x-ray lithography, for more precise integrated-circuit etching. LLNL's laser could produce the shorter wavelengths of light needed to produce higher resolution features as fine as 0.1 microns, possibly replacing conventional optical lithography techniques. IBM is building a \$700 million x-ray lithography facility using a high-power energy source called a synchrotron. If the company's technology is successful, then small producers who cannot afford a synchrotron (\$100 million) could use LLNL's laser (a few million dollars).

■ For more information, contact James Daly via telephone at (201) 843-7800, ext.12, or via E-mail at metalimp@ix.netcom.com. You can also visit Metal Improvement's Web site at <http://www.metalimprovement.com>.



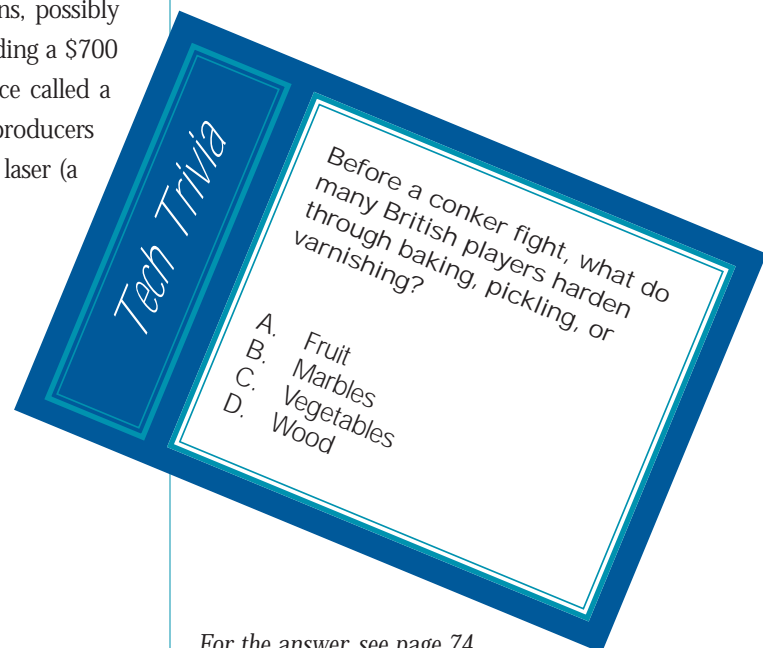
What Does It Mean to You?

Laser peening means jet engine components will be made stronger and last longer, thereby making flying safer.

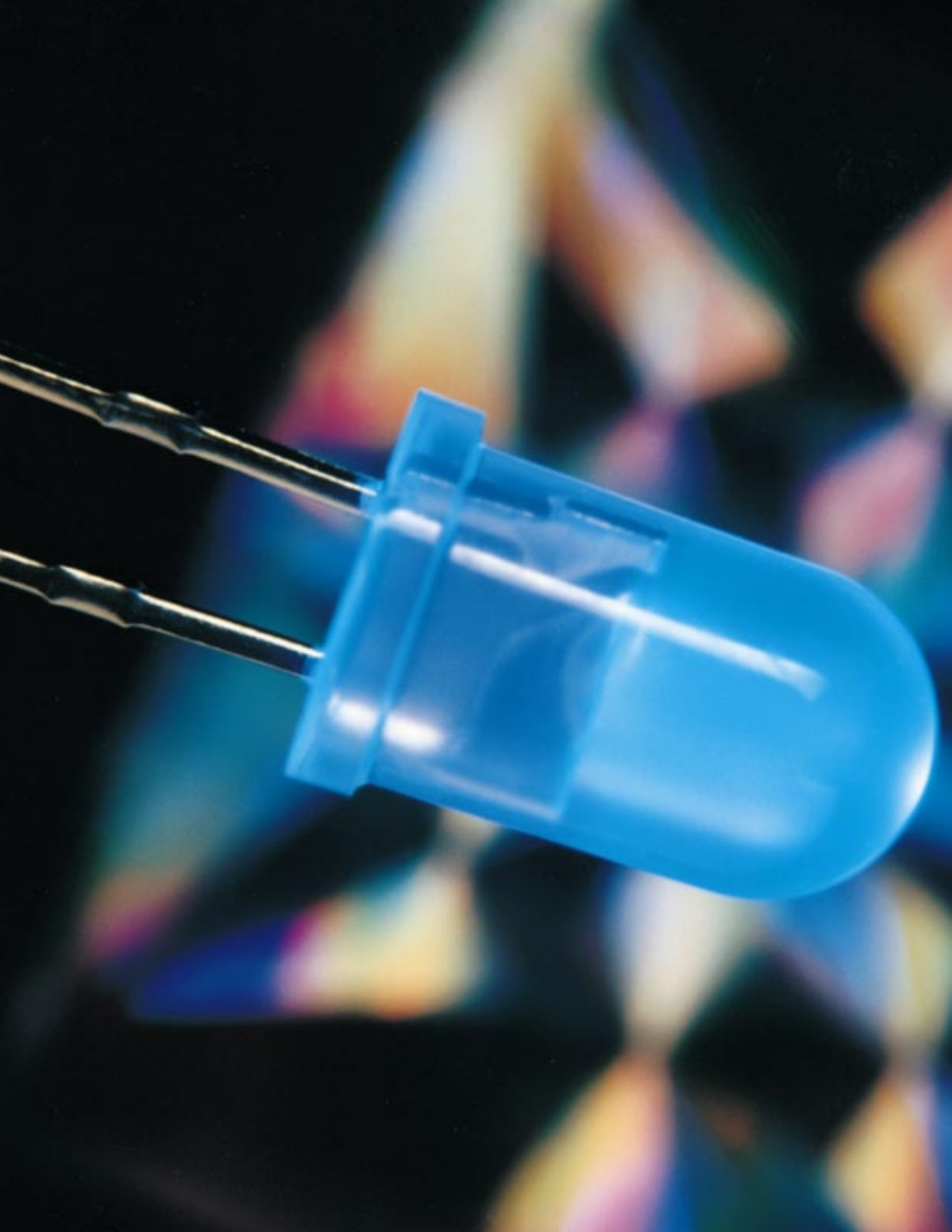


What Does It Mean to Our Nation?

Laser peening may create a new industry that can increase the value of manufactured metal products such as hip joint implants and jet engine blades.



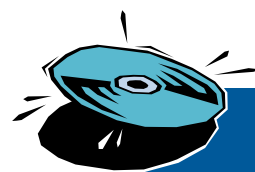
For the answer, see page 74.



MATERIALS TECHNOLOGIES

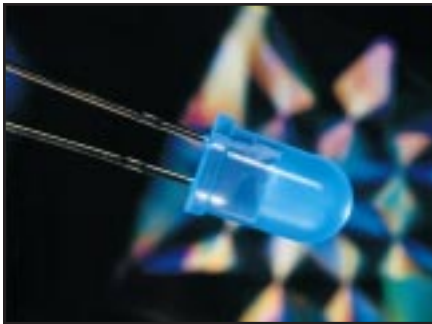
Think of BMDO technology
transfer the next time you

- View an electronic display
at an outdoor stadium.
- Drink a cool, refreshing
glass of water.
- Boot up your computer
and access the disk drive.
- Add a lubricant to your
car's engine oil.



SILICON CARBIDE IS READY FOR PRIME TIME

Process technology for low-cost, low-defect silicon carbide is enabling cutting-edge electronic devices, and paving the way for other novel components.



■ Cree's scientists created a light-emitting diode (pictured above) that emits an intense, brilliant blue light when an electrical current is applied.



■ Lab-created moissanite gemstones (pictured above) are being marketed to the jewelry industry as a substitute for diamonds.

The physical and electronic properties of silicon carbide (SiC) make it an attractive semiconductor material for the 21st century. For example, SiC's wide energy bandgap will enable the creation of new electronic devices that can operate in extremely high temperatures or emit and detect short wavelength light. However, improvements in SiC crystal growth and device fabrication processes are needed before these devices can be scaled up and incorporated into electronic systems.

Cree Research, Inc. (Durham, CA), has put to use new process technology that overcomes many of the basic technical obstacles that have blocked the commercialization of SiC semiconductors. Cree's technology significantly reduces the defect density and cost of the company's SiC wafers, making the material commercially viable for some uses and nearly so for many others. In addition, it is enabling the company to develop a wide range of advanced semiconductor electronic products, such as blue light-emitting diodes (LEDs) and displays.

Many of Cree's process innovations can be traced to the SiC research it performed under several BMDO contracts. BMDO's original vision of space-based systems required radiation-hardened electronics. This hardening property allays the fear of space radiation degrading or disrupting the operation of electronic devices and components on monitoring, tracking, and even weapons-carrying satellites.

Colorful splash. The company's first commercial products using this SiC process technology are its blue LEDs. Cree currently sells LEDs to manufacturers who incorporate them into LED lamps. For example, Cree's largest customer, Siemens A.G., is using the blue LED for automobile dashboard lighting. Other commercial applications for blue LEDs include large-scale flat-panel displays, color recognition sensors, color slide and film scanners, and digital color photographic printers. As production costs decrease and volume increases, Cree expects to see broader applications emerge for its blue LEDs.

Another commercial product that benefits from Cree's SiC process technology is the Real Color Module™, a device only three inches thick and loaded with LEDs capable of representing the entire color spectrum. The module provides a low-cost and effective way of displaying text messages, which can be easily changed and updated. Near-term potential applications for the module include

gaming, casinos, and advertising displays. Recently, Rainbow Vision Company, Ltd., placed Cree's largest one-time order for 800 Real Color Modules. The devices will be used in a live-action replay board for a sports arena.

In addition to these commercial products, Cree has developed a highly successful business using the process technology to manufacture and supply SiC wafers to corporate, government, and university programs. These customers are, in turn, using these products to develop new high-frequency, high-power, and high-temperature devices. Cree recently concluded an agreement to supply Asea Brown Boveri AB, a manufacturer of SiC power semiconductors, with SiC wafers worth a total of \$2.4 million.

On the horizon. Cree is banking on the future potential of its SiC process technology by investigating potential business opportunities in blue lasers, microwave devices, and power devices. For example, Cree's blue LED research and development efforts have paved the way for developing a blue laser. Recently, the company validated the use of SiC as a viable substrate for blue lasers by showing a pulsed and continuous wave laser operation. Blue lasers are expected to enable a dramatic increase in optical data storage capacity. Because of the blue laser's short wavelength, it could increase storage capacity fourfold.

To generate a new level of commercial interest in SiC microwave devices, Cree recently demonstrated a high-powered SiC metal-semiconductor field-effect transistor. Silicon-based microwave products capable of operating at higher power levels are currently available, but these are typically multiple-chip packages. SiC microwave transistors, if packaged in a single-chip product, could offer power levels substantially higher than other solid-state products now on the market.

And on a completely different track, Cree serendipitously created a sparkling new business opportunity for colorless SiC crystals. While improving the SiC growth process, Cree's scientists accidentally synthesized clear moissanite, a carbon-based mineral that has physical characteristics closer to diamond than any other known gemstone material. Recognizing this material could be easily mistaken for diamond, Cree formed a business alliance with C3, Inc., to explore the jewelry market. Using Cree's colorless SiC crystals, C3 is now, or will soon be, marketing moissanite gemstones through jewelry retailers in 47 U.S. cities.

■ For more information, contact Neal Hunter via telephone at (919) 361-5709 or via E-mail at neal_hunter@cree.com. You can also visit Cree's Web site at <http://www.cree.com>.



What Does It Mean to You?

Low-cost, defect-free silicon carbide is enabling many commercial products, from full-color displays and moving message signs to high-power radio frequency and microwave transmitters.



What Does It Mean to Our Nation?

Silicon carbide technology can lead to more efficient power transistors for lighting, heating, and air conditioning products, which could reduce national energy consumption and, in turn, reduce pollution resulting from energy production.

Tech Trivia

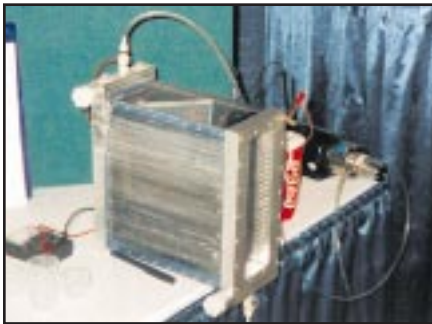
When incandescent lights for the display on the Goodyear blimp *Spirit of Akron* were replaced with brighter light-emitting diodes, what was the result?

- A. A decrease of 250 pounds
- B. A decrease of 500 pounds
- C. An increase of 250 pounds
- D. An increase of 500 pounds

For the answer, see page 74.

CARBON AEROGEL REALLY CLEANS UP WATER

An energy-efficient water treatment tool that makes salty water safe to drink offers new hope to countries blighted by serious water shortages.



■ This water purification unit (pictured above) contains 1,000 square feet of carbon aerogel surface area, yet occupies only a few cubic feet of space.



■ Using carbon aerogel (pictured above) like a microscopic sponge, capacitive deionization is an efficient, economical process for purifying water.

How about a cool, refreshing cup of seawater? In California, the towns of Santa Barbara and Avalon have begun using desalinization methods to remove the salt from seawater, making it suitable for drinking. Desalination is not used much at the moment because it is too expensive. But as both the demand for fresh water and our population increase, you can expect to see more desalination occurring, especially in areas such as California and Texas.

Other countries, too, are experiencing serious water shortages. According to an analysis by Population Action International, more than 430 million people—8 percent of the world's population—are living in countries affected by water stress or outright scarcity. For example, China now officially recognizes that 300 of its largest cities are facing water scarcity.

But the world may soon change the way it looks at salty water, thanks to capacitive deionization (CDI) technology recently developed by Lawrence Livermore National Laboratory (Livermore, CA). An energy-efficient and economical process, CDI uses electrochemical cells treated with a unique material to extract salt and other nonorganic contaminants from water. In certain regions of the United States, and in underdeveloped countries around the globe, CDI units could sustain water and ease scarcity.

Frozen smoke. The key to CDI is carbon aerogel, a highly porous material with nanometer-size cells. In the early 1990s, carbon aerogel research at the lab was partially funded by BMDO's space power program to develop lighter batteries. Made of 96 percent air, carbon aerogel appears more like dark frozen smoke than gel. An intriguing characteristic of this material is its large "internal" surface area. If you could flatten out all of the surfaces lining the tiny pores within a sugar-cube-size piece of carbon aerogel, researchers believe the surface would cover five basketball courts. This versatile manmade material promises a wide range of uses, from insulating windows and appliances to extracting salt from seawater.

The Far West Group, Inc. (FWG; Tucson, AZ), a water resources management business, recognized the worldwide potential of CDI for water treatment services. In 1997, the company established a licensing agreement with the lab to commercialize CDI technology. A second license was established to ensure that FWG could manufacture enough carbon aerogel to support its commercial plan.

CDI is better than many of today's desalination options. "CDI systems would consume considerably less energy per unit of purified water than competing technologies, such as thermal distillation or reverse osmosis (RO)," says Jack Reese, FWG's vice president of marketing. "In fact, CDI could eventually replace RO because of greater energy efficiency and lower maintenance costs. And, when the desalinization technology is needed only on a seasonal or periodic basis, CDI has much lower costs than competing technologies because of its indefinite shelf life." Carbon aerogel will store for years without degradation.

Salt bricks. Among the many business opportunities for CDI systems is treating brackish and salty water, providing drinkable water and agricultural-grade water for towns and farms in water-scarce regions. In addition, FWG believes that it could spin off another business that sells the salt it removes from the treatment process. For example, the company is investigating a recent discovery that salt bricks stronger than concrete can be made. Using CDI, semiconductor manufacturers could produce ultrapure water for semiconductor manufacturing. Another application of CDI is extracting harmful contaminants from waste water, which can help industry reclaim heavy metals or hazardous materials from waste streams.

FWG has implemented a multifaceted approach to commercialization. In addition to demonstrating CDI's capabilities in both the United States and abroad, the company is consulting with Boeing Aerospace and Interglobal, Inc., for international distribution. FWG recently succeeded in obtaining \$375,000 from Electric and Gas Technology to finance the installation of a proof-of-performance system in Carlsbad, California. Additional funding is being sought to speed development of this technology.

FWG is steadily moving toward a final design. The company has reduced the weight of the original CDI prototype unit by 90 percent and significantly cut manufacturing costs. Looking ahead, it hopes to start building CDI systems in 1999.

■ For more information, contact Clark Vaught via telephone at (520) 293-9778 or via E-mail at farwest@farwestgroup.com. You can also visit Far West Group's Web site at <http://www.farwestgroup.com>.



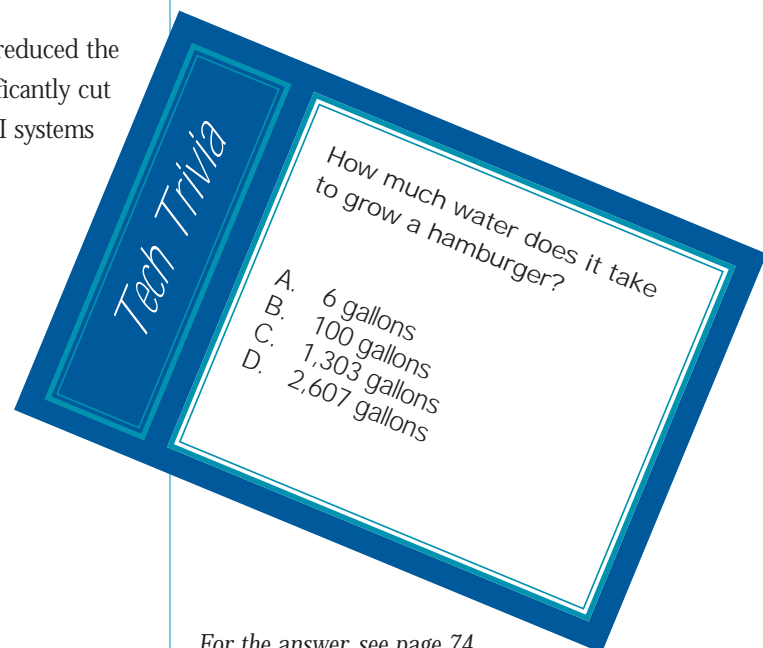
What Does It Mean to You?

With capacitive deionization, you can remove enough salt in brackish and sea water to drink it or use it to sustain farms and lawns.



What Does It Mean to Our Nation?

Capacitive deionization can help water-scarce regions like California and Texas increase freshwater supplies for domestic and agriculture applications, potentially eliminating water-use restrictions.



For the answer, see page 74.

ALLOYS MAKE LOSING WEIGHT EASY

Aluminum-beryllium alloys fill the need for stiff, lightweight materials in golf clubs, communications satellites, and computer disk drives.



■ Precision investment-cast Beralcast® components (pictured above) are used in a wide variety of aerospace, defense, and commercial applications.

Manufacturers have long recognized beryllium for its superior attributes—its light weight, high stiffness, and superior ductility. But the dark grey metal is expensive and brittle, making it difficult to mass-produce into parts, especially complex ones. So far, commercial industries have shied away from using beryllium in their products, resorting to less exotic materials such as aluminum.

Over the years, many attempts have been made to combine beryllium and aluminum, which could theoretically produce parts that perform better than those made of conventional materials, at a price much more affordable than that of pure beryllium. Although simple enough in concept, the alloy's production was hindered for many years because conventional manufacturing techniques were inefficient and wasteful.

Starmet Corporation (Concord, MA), formerly Nuclear Metals, Inc., has developed a method for mass-producing parts made from a family of materials called Beralcast® using aluminum-beryllium alloys. Its casting process allows very complex near-net and net shapes to be fabricated with little or no finished machining—an industry first. In general, any part that can be investment cast in aluminum can also be investment cast in Beralcast. For example, aluminum-based armatures and support structures for high-end computer disk drives and communications satellites, respectively, have been successfully reproduced in Beralcast.

Successful trio. The key to Starmet's success is three new alloys, namely Beralcast 363, 191, and 310. These materials have a fine-grain, homogenous, as-cast microstructure. Their composition is designed to minimize the effects of segregation, porosity, and low strengths. Therefore, they can be readily cast into complex shapes with greatly improved strength and ductility and significantly reduced weight, as compared with other competing materials. Starmet developed the Beralcast process several years ago with validation funding from BMDO contracts for ballistic missile defense systems.

Although difficult to achieve, Starmet's breakthrough provides important technology for weight-critical and stiffness-critical programs. "In making Beralcast alloys, it took us over 400 attempts to find the right combinations of aluminum, beryllium, and trace elements," says Frank Vumbaco, Starmet's vice president of corporate communications. "Beralcast parts are 22 percent lighter than alu-

minum components but have the stiffness of steel. Because of this stiffness, parts can be redesigned using thinner walls. As a result, finished Beralcast parts could weigh half as much as aluminum ones.”

Starmet’s development of Beralcast led to the spinning out or formation of several companies, including two wholly owned subsidiaries, Starmet Commercial Casting and Starmet Aerocast. Another company, TrioStar, also formed to take advantage of Beralcast. In 1997, several commercial and military groups established agreements with these companies to use Beralcast in their systems.

For example, Starmet Commercial Casting has received more than \$1 million in contracts from four major companies to use Beralcast material in high-end computer disk drives. Armatures made of Beralcast alloys allow disk drives to retrieve more electronic data at a faster rate than those made from aluminum because the material’s stiffness and resulting damping qualities are 4 to 10 times better than aluminum, depending on the driving and resonance frequencies. Starmet Commercial Casting has been manufacturing prototype Beralcast components and expects to mass-produce computer disk drive armatures in mid-1999.

Flying high. Teaming with Advanced Product Laboratories and R-Cubed Composites, Starmet Commercial Casting also formed a joint venture corporation in late 1997, called TrioStar (West Jordan, UT). TrioStar offers the unique capability to integrate resin matrix composite and metallic structures into a unified design for application in such weight-critical programs as low-Earth-orbiting satellites for global communications networks. The bulk of the technology also surrounds Starmet’s patented family of Beralcast alloys. Because Beralcast is light in weight, has a high modulus of elasticity, and can be precision cast for three-dimensional material stability, these alloys are attractive for advanced sensor and guidance structures in flight and satellite systems.

On a lighter note, Starmet is investigating the use of Beralcast in golf clubs and high-end racing bicycles. Working with several equipment manufacturers, the company is testing Beralcast alloys for replacing the club’s head and shaft, which may increase the speed of the user’s swing. It also has supplied Beralcast alloys to Beyond Fabrications, producers of beryllium-based bicycles. The Beralcast frames of these bikes weigh about two pounds, which is about half the weight of aluminum frames.

■ For more information, contact Frank Vumbaco via telephone at (978) 369-5410, ext. 296, or via E-mail at fvumbaco@starmet.com. You can also visit Starmet’s Web site at <http://www.starmet.com>.



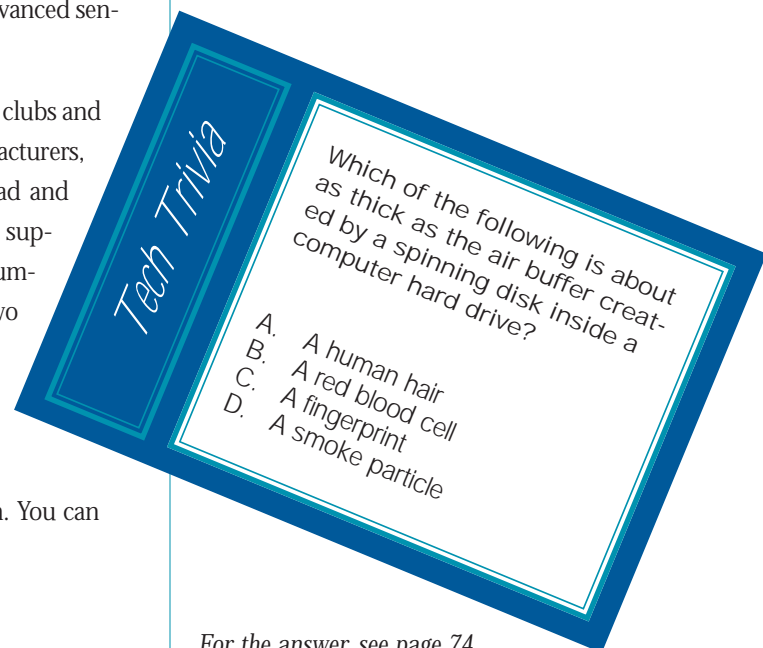
What Does It Mean to You?

Beralcast alloys will be greatly appreciated by both computer users and sports enthusiasts, allowing manufacturers to produce faster, larger hard disk drives and lighter, stronger golf clubs.



What Does It Mean to Our Nation?

Beralcast alloys will lower costs in weight-critical programs such as low-Earth-orbiting satellites for global communications networks, enabling commercial and government space programs to reduce mission budgets.



For the answer, see page 74.

OIL ADDITIVE KEEPS ENGINES HEALTHY

This lubricant repairs worn-out spots caused by metal-to-metal contact in automotive engines, restoring lost power, performance, and gas mileage.



■ RITE SURGE™ (pictured above) is a lead-free engine oil additive developed by Materials Modification.

Before you turn that ignition key, answer this question: Do you know where your car's engine oil is? If you believe the oil is in the engine, you are wrong. Actually, gravity has pulled the engine oil back into the oil pan underneath the car. The oil pump has not yet circulated oil through the engine.

Dry cold starts, as they are called, are particularly hard on your car's engine. Engineering studies show that 70 to 80 percent of all engine wear occurs during that 60 second dry-start period when an engine is first started. Wear is caused by metal-to-metal grinding, and it can destroy vital engine components such as camshafts, leading to engine breakdowns.

Materials Modification, Inc. (MMI; Fairfax, VA), has developed an innovative lubricant that can seal worn-out spots in the engine. By filling these spots, this oil additive can significantly reduce metal-to-metal contact, especially during dry cold starts. Reduced wear also leads to better performance—engine compression and horsepower are increased, giving your car more pep and power. And less engine wear saves you money, in terms of better gas mileage and lower engine repair bills.

Getting the right mix. MMI's oil additive is a unique blend of soft metal and copper powders. Ordinarily, these powders would be difficult to mix because the soft metal nanoparticles do not bond well to copper nanoparticles. But MMI adds several proprietary chemicals to increase particle consolidation and create a homogeneously distributed product. BMD's SBIR program funded MMI to develop this materials technology for self-lubricating bearings in space applications. These bearings would be superior to greased bearings, which are prone to outgassing in the vacuum of space. Bearings are typically found in moving mechanical assemblies.

Before pursuing the automotive engine application, MMI discovered commercial satellite and brazing opportunities. "We believe our materials technology would be great for making self-lubricating bearings for communications satellites," says Dr. T.S. Sudarshan, MMI's technical director. "Most people believe that battery life limits satellite lifetimes, but it really is the bearings. Over time, bearings lose their lubrication and the metal-to-metal grinding often corrupts satellite transmissions." Dr. Sudarshan adds that the technology could also be

used to make high-temperature brazing alloys with the fluidity of soft metal but the strength of copper.

MMI researchers also tested the material, along with regular motor oil, in car engines. These tests were very successful, which encouraged MMI to consider how to introduce this product to the automotive market. Unable to commercialize the technology themselves, MMI sold its rights to a group of individuals with significant experience in the automotive industry. This group formed a company to market the new materials technology as an engine oil additive. For three years after this deal was completed, MMI received royalty payments.

Slick business. The automotive company annually sells more than 4 million cans of the engine oil additive, split evenly between Europe and the United States. In the United States, the company's product can be found on the shelves of many automotive product retailers, including TrakAuto, WalMart, and Kmart.

In recent years, the Environmental Protection Agency has become increasingly concerned about lead-based products and their adverse effects on the environment. It has proposed environmental regulations that would ban the production and sale of many of these products by the year 2000. These regulations could significantly curtail the sale of lead-containing additives for car engines.

To address these environmental concerns, MMI has formulated a new lead-free engine oil additive called RITE SURGE™ while working on a U.S. Army contract. This additive, which is environmentally safe, is specifically designed for high-mileage vehicles. Like its predecessor, it repairs and seals grooves and other damage to engine parts caused by wear. MMI is ready to begin production of RITE SURGE and is currently seeking national distributors.

■ For more information, contact Dr. T.S. Sudarshan via telephone at (703) 560-1371 or via E-mail at sudarshan@compuserve.com. You can also visit MMI's Web site at <http://www.matmod.com>.



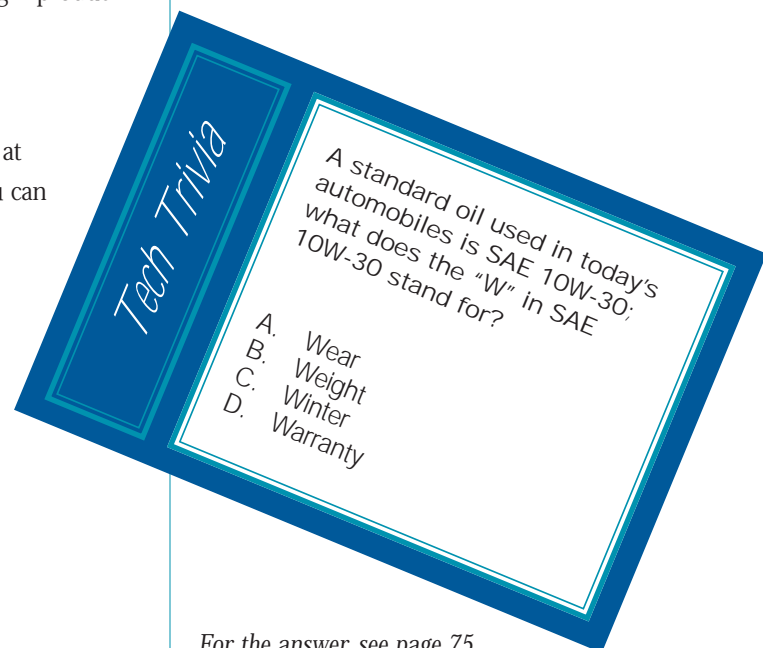
What Does It Mean to You?

Oil additives for automotive engines save you money by preventing untimely engine breakdowns and even vehicle replacements.



What Does It Mean to Our Nation?

Oil additives help car engines achieve better gas mileage, which results in less air pollution.



For the answer, see page 75.



OPTICAL AND SENSOR TECHNOLOGIES

Think of BMDO technology
transfer the next time you

- Ship a package via Federal Express.
- Read that law enforcement officials used fingerprint recognition to solve a crime.
- Ride a mountain bike on bumpy trails.
- Fly in icy conditions and enjoy a safe landing.



ADAPTIVE OPTICS SEE BRIGHT FUTURE IN SHIPPING, MOVIE PRODUCTION

Real-time data processing techniques for adaptive optics greatly enhance computer-generated animation and industrial motion and control.



■ An Adaptive Optics Associates package-scanning system (pictured in the background) keeps parcels moving at Federal Express.

How do you create the illusion of milling crowds on the deck of an ill-fated passenger ship? Digital Domain faced that question when putting together some animation clips for the recent blockbuster film *Titanic*. Props were used much of the time for wide-angle ship views, but other images were needed to make these shots more realistic and believable to the audience.

Using motion capture technology developed in conjunction with Adaptive Optics Associates, Inc. (AOA; Cambridge, MA), Digital Domain's animators successfully generated this populated illusion for the movie. AOA's computer animation and visualization software lends realism to motion capture data used in computer-assisted animation. For example, AOA's products have been used by animators to make commercials for Reebok. In addition, AOA's FaceTrax™ facial expression capture system has been used by a production company to create virtual reality settings for a CBS weekly children's program, and by British Broadcasting Corporation to develop the world's first real-time animated cartoon character appearing "live" on a television program.

AOA's motion capture systems use reflective sensors that are pasted onto critical moving parts of a body or the most mobile features of the face. Cameras, operating at up to 240 frames per second, record the patterns of motion from the reflective dots. This process allows computer animators to create "control points" based on the captured movements; these points are used to guide the frame-by-frame rendering of nearly lifelike 2-D or 3-D models. Using commercially available rendering software, the animator can then overlay the figure with more sophisticated imagery. AOA's systems use real-time data processing techniques that were originally developed for adaptive optics research for BMDO's predecessor, the Strategic Defense Initiative Organization.

Capturing motion data. Motion capture technology could eventually become an important part of AOA's business. "The ability to collect real-world movement and facial expression in real time using digital camera and tracking technology is not only advantageous for animation, but also for industrial motion and control applications," says Anderson Maddocks, marketing director for AOA. "What AOA has learned developing ways to capture motion data for special effects has helped to improve the robustness of its technologies and enabled new applications."

In addition to assisting with computer-generated animation, AOA has found less entertaining but equally important applications for its imaging technology in expediting freight transport. AOA has developed a package scanning and dimensioning system for Federal Express Corporation (FedEx). More than 50 units have been installed throughout FedEx's major hub-and-spoke locations, helping the company move large parcels more effectively.

Overnight packages are not always nice, neat, blue-and-orange boxes. They can be lumpy, tape-wrapped parcels, round tins of cookies, or car mufflers, all with bar-coded labels slapped on them. Mounted above the package-moving conveyor belt, AOA's dimensional imaging system uses laser radar technology and bar-code scanners to take the guesswork out of pricing odd shapes and sizes of packages.

Scans odd-shaped parcels. The system locates and reads bar codes on the fly, scanning up to 15,000 parcels per hour on conveyor belts that move at 300 feet per minute. A unique feature of this system is its ability to accurately measure parcels that are large, irregularly shaped, touching each other, and strewn in an irregular fashion on the conveyor belt. The scanners measure with 99.7 percent accuracy parcels as large as 3 x 5 x 8 feet, to within a half-inch of their length and width and a quarter-inch of their height.

After obtaining information about the packages, the system makes the data available for a variety of uses within FedEx's information systems. This information helps the company plan and manage the package-processing operation and assess the number of places and trucks it will need at various locations. "We're providing them with statistics they never had before," says Maddocks. FedEx is using the system not only in its largest on-airport sorting facilities—called hubs—but also at smaller facilities that form the "spokes" of its hub-and-spoke transportation network.

While popularizing its technology, AOA still serves the sophisticated optical needs of the astronomical community. Some of its optical products are part of the adaptive optics systems on the Keck I and II telescopes on Mauna Kea, Hawaii. AOA also supplied some wavefront sensors for laser guide star testing at the Lick Observatory on Mount Hamilton near San Jose, California. Recently, it installed a complete adaptive optics system for the Max Planck Institute for Astronomy on a 3.5-meter telescope in Calar Alto, Spain.

■ For more information, contact Cameron Dryden via telephone at (617) 864-0201 or via E-mail at cameron@aoainc.com. You can also visit AOA's Web site at <http://www.aoainc.com>.



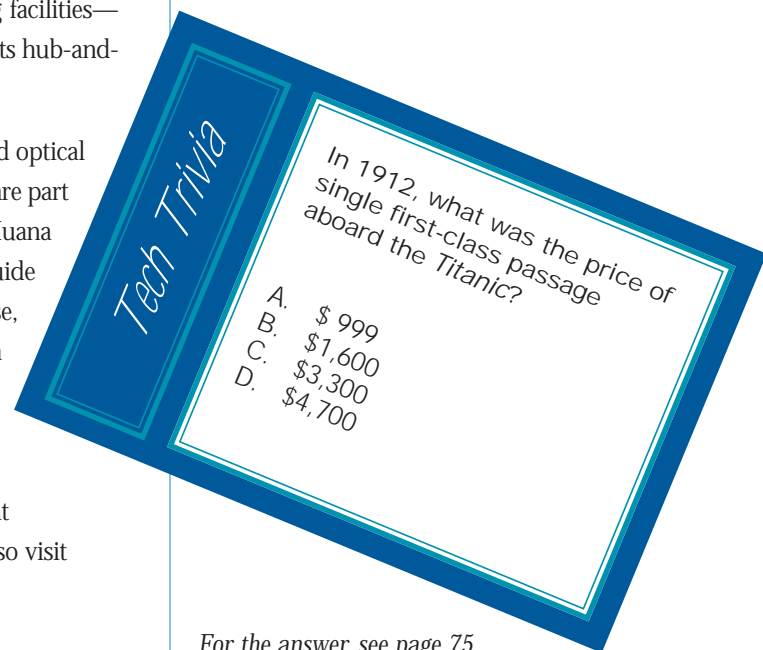
What Does It Mean to You?

Real-time data processing in special effects systems means that animators can make computer-generated characters and scenery more lifelike, bringing more realism to the silver screen.



What Does It Mean to Our Nation?

Real-time data processing in mass scanning systems helps reduce operational costs for industry by improving the effectiveness of production lines and for shipping companies by expediting the delivery of freight.



For the answer, see page 75.

CORRELATOR HELPS PUT A FINGER ON CRIME, PRODUCTION PROBLEMS

A superfast optical correlator system may help machines “see” faster, allowing real-time inspection of human fingerprints and assembly line products.



■ QuantalImage researchers have reduced the size of its fingerprint recognition system so that the “guts” of the technology now fit completely inside two disk drive bays on the PC (pictured above).

Once, our eyes were all the quality control we needed. These days, as production lines have speeded up, electronic eyes do most of the inspecting. But even today's digital machines are struggling to process imagery fast enough, increasing the possibility of costly mistakes. This will soon change, though.

CoreTek, Inc. (Burlington, MA), has developed a fast optical correlator system that can swiftly crunch images, helping to drive the conversion of all-optical-processing systems into powerful processing products for pattern-matching applications. The system, which can process more than 4,000 images per second, promises dramatic speedups for such jobs as matching fingerprints and detecting damaged products on assembly lines. For example, finding a match of a fingerprint electronically among millions typically takes several days. Soon, it may take only seconds.

The key to the system's throughput is the use of spatial light modulators (SLMs). Unlike digital imaging systems, which require a high-speed electronic camera, SLMs capture images directly from the environment, reducing the time typically lost to digitization and mathematical operations. The SLMs are made of a newly created quantum-well-based material that increases the speed and sensitivity to a level greater than what is available in most similar devices. For example, they are 1,000 times faster and 10 to 20 times more sensitive than commercially available liquid crystal SLMs. BMDO's SBIR program funded CoreTek to develop the optical image processing technology to speed up the process of locating and tracking a missile.

Licensing deals. Several licensing agreements and prototype demonstrations indicate that CoreTek is serious about commercializing its technologies. CoreTek established licensing deals with a photonics company in Huntsville, Alabama, for its correlator technology, and with an opto-electronic company in the Northeast for its modulator technology. These deals secured much-needed funding to continue product development and commercialization activities. CoreTek also demonstrated its optical correlator prototype at a manufacturing plant of a major fruit juice company. Placed near the conveyor belt, the optical processor was able to quickly identify defective fruit, enabling the manufacturer to improve quality control on the spot.

Focusing on law enforcement, CoreTek has incorporated its optical correlator technology into a high-speed optical fingerprint identification (OFID) system. The original prototype processed more than 1,000 images per second, but recent improvements have almost quadrupled its throughput. At this rate, the system can identify a print from a 500,000-fingerprint database in less than 10 seconds. Existing electronic technology claims to be able to match images at rates of 3,000 images per second, but only after the number of potential matches has been limited by preprocessing information.

The OFID technology developed at CoreTek has been licensed to QuantaImage, Inc. (Burlington, MA), a newly formed spinoff company. Currently, QuantaImage is making hardware and software modifications to the existing prototype in preparation for marketing to potential customers. The hardware will consist of an ultracompact 1 x 2 x 4-in. optical correlator unit interfaced with an electronic database (a personal computer). The software is being modified to prefilter the database based on the demographics and to ensure the quality of fingerprints so the error-free laboratory performance can be sustained in real operating conditions.

Fingering criminals. QuantaImage's superfast fingerprint identification system is targeted for use in environments where positive identification needs to be established quickly and reliably. "Our optical processor can process four images every millisecond, compared with every 4 seconds for other commercially available systems," says Ergun Canoglu, vice president of QuantaImage. "This speed advantage makes it attractive for a variety of pattern-matching applications, from controlling products on high-speed conveyor belts to identifying criminal fingerprints on large electronic databases."

According to QuantaImage, two emerging markets for fingerprint identification are corporate security and World Wide Web (WWW) access. MasterCard annually loses \$450 million, or 9 cents of every \$100 in charges, to credit card fraud. Using digital fingerprint scanning technology in a recent test, MasterCard cut fraudulent charges by 80 percent. Fingerprints also could be used to allow WWW browsers access to a company's network and files.

■ For more information, contact Ergun Canoglu via telephone at (781) 221-3759 or via E-mail at ergun@coretekinc.com.



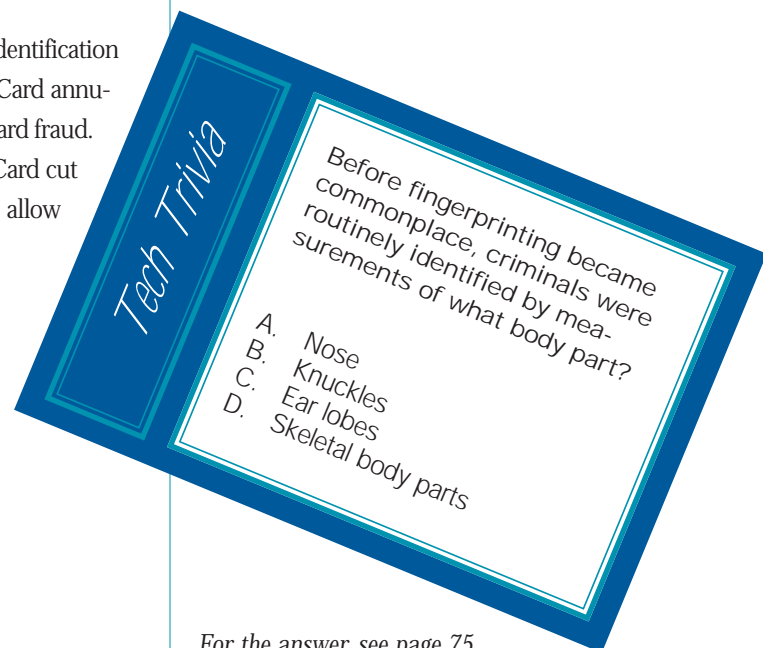
What Does It Mean to You?

Building optical image processors into scanning systems can help law enforcement officials solve crimes and catch criminals, making neighborhoods safer.



What Does It Mean to Our Nation?

Scanning systems based on optical image processing could help the Federal Bureau of Investigation reduce the backlog of fingerprint analysis cases.



For the answer, see page 75.

SHOCKING NEWS: IT'S A BUMP BUSTER!

The world's first bicycle shock with a "brain" cushions against jolts, allowing peddlers to blast down trails with greater control and safety.



■ The world's first bicycle shock with a "brain," Smart Shock (pictured above) maintains control in all speed and terrain extremes by compensating for any impact in the blink of an eye.



■ A bicyclist (pictured above) may feel no fear using Smart Shock.

Mountain bikers already wear safety gear to soften their falls, but now they can buy something much more comforting: a bicycle shock with a "brain." No need to think when using it—this computer-controlled suspension automatically adjusts from hard to soft to provide a smoother ride. It allows mountain bikers to concentrate on riding, not on bracing for bumps.

Active Control eXperts, Inc. (ACX; Cambridge, MA), in conjunction with K2 BIKE and Noleen Shocks, developed the cutting-edge "Smart Shock" technology. Capable of compensating for any impact in the blink of an eye, the Smart Shock not only increases overall ride comfort but keeps the front wheel in contact with the road, which helps riders maintain control across all speeds and terrains. Better yet, it only requires a single nine-volt battery to operate and weighs less than a pound.

Using microprocessor, piezoelectric actuator, and sensor technologies, the Smart Shock is the first to provide continuously variable damping. Once activated, the chip allows the damping system to establish its nominal setting. As long as the shock piston does not travel too far down the shaft—that is, when the bike is speeding over smooth or slightly bumpy terrain—the chip will tell the sensor to provide a series of nominal and soft damping forces. The sensor, in turn, signals the actuator system to adjust the shock damping.

If the shock piston travels further down the shaft, as in the case of a big hit, the sensor sounds the alarm and the microprocessor initially adds soft damping to cushion the blow and then hard damping to prevent the shaft from bottoming out. With the sensor monitoring the speed and position of the shock piston about 1,000 times per second, Smart Shock can handle any kind of trail condition on the fly.

Metal sandwich. The sensor technology is based on the giant magnetoresistive (GMR) effect, in which metals show slight changes in electrical resistance when placed in a magnetic field. Sandwiches made up of very thin layers of metals can amplify this effect. Seeing the potential of this technology to dramatically increase the sensitivity of sensors, Nonvolatile Electronics, Inc. (NVE; Eden Prairie, MN), developed novel GMR material and processing technology with funding from BMDO's SBIR program in the early 1990s.

Since then, NVE has leveraged this research into a line of magnetic sensing products with widespread applications. For example, Nu-Metrics (Scottsdale, AZ) is selling Groundhog® and Hi-Star traffic monitors that use NVE's GMR sensors to obtain real-time traffic data, such as traffic speed and volume, types of vehicles, and distances between vehicles. In addition, NVE's GMR sensors are being used in medical instruments, paint spraying-equipment, and automatic braking systems for automobiles. But perhaps the most interesting consumer application to date has been the mountain bike suspension system, Smart Shock.

"Smart Shock has a distinct advantage over conventional manually adjusted shocks," says Matt Miller, K2 BIKE's marketing services manager. "With conventional shocks, once you set it, you're stuck—unless you get off the bike to change it. With the Smart Shock, however, no adjustment is necessary because the microprocessor does it for you instantaneously."

Smart mode. The Smart Shock has three modes of operation: soft, hard, and smart. Soft mode provides lower damping, giving a plusher ride at low speeds. Hard mode provides greater damping, giving a firmer ride at high speeds or while biking uphill. Smart mode is the best of both worlds, providing a variable level of damping over a wide range of terrain conditions and speeds. Bike riders can toggle each mode using a button on a handlebar-mounted box.

The Smart Shock marks the first high-volume, commercial application of electronics to mountain bike suspensions. This innovation is now available on K2's 1998 full-suspension bikes, which cost between \$2,000 and \$4,000. "We are expecting a huge market response to this product," says Adam Bogue, ACX's vice president of marketing. He also mentioned that ACX is working on next-generation bicycle products that offer even smoother and more efficient rides.

■ For more information about ACX, contact Adam Bogue via telephone at (617) 577-0700 or via E-mail at bogue@acx.com. You can also visit ACX's Web site at <http://www.acx.com>.

■ For more information about NVE, contact Robert Schneider via telephone at (612) 829-9217 or via E-mail at bob_schneider@nve.com. You can also visit NVE's Web site at <http://www.nve.com>.



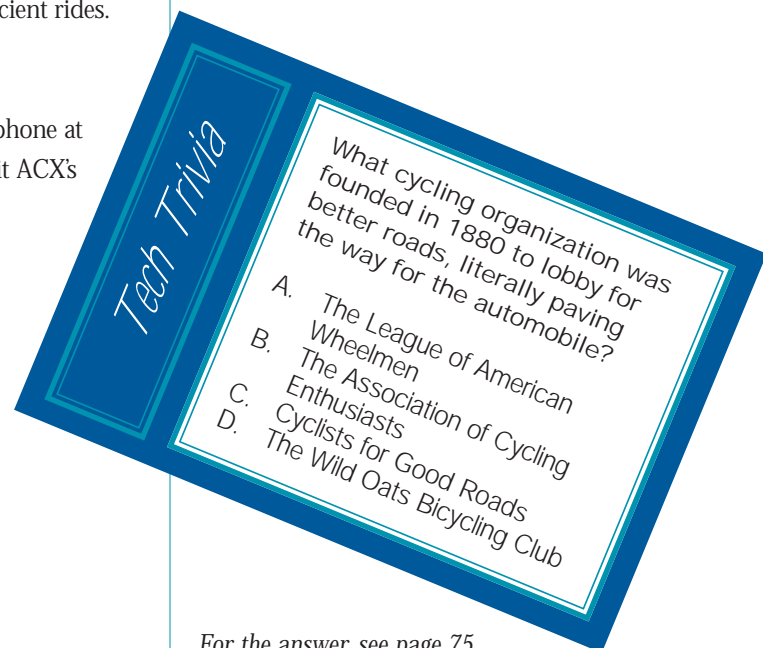
What Does It Mean to You?

Smart Shock was developed for mountain bikers who want maximum comfort and control on rugged terrains.



What Does It Mean to Our Nation?

Electronic suspension systems will help millions of Americans to enjoy the health, recreational, and pollution-prevention benefits of bicycling.



For the answer, see page 75.

THIS DEVICE IS NICE FOR DETECTING ICE

A simple, low-cost sensor reliably detects and measures ice formation on aircraft airfoils during flight, helping pilots avoid the danger of icing.



■ Innovative Dynamics' technology will soon detect and remove ice on the Raytheon Premier 1, a light business jet (pictured above, courtesy of Raytheon Aircraft).

Icing was a contributing factor in at least eight fatal crashes involving U.S. commercial aircraft in the past decade, including the 1994 crash of an American Eagle ATR-72 turboprop in Roselawn, Indiana, that killed all 68 people onboard. Government investigators say ice has led to many accidents and near crashes over the years, including a 1993 incident involving a Continental Express Embraer 120 that suddenly spun out of control and plunged 12,000 feet before the pilot regained control and made an emergency landing.

Despite that history, most aircraft still rely on fairly primitive systems to monitor and remove ice. According to the *Wall Street Journal*, as late as 1997 the Federal Aviation Administration (FAA) still advised pilots of commuter planes that the best way to detect hazardous icing is to look out of the window for the telltale signs of buildup. Unfortunately, it is not always easy for the pilot to tell if clear ice is accumulating.

Addressing this problem, Innovative Dynamics, Inc. (IDI; Ithaca, NY), has developed an ice sensor that can automatically alert pilots when ice is forming. By providing advanced warning of icy buildup, the sensor allows pilots to either activate the deicing system to break ice up in flight or change the plane's flight path to take it out of harm's way. The sensor's flush-mounted design allows installation on fuel tanks and other surfaces that should not be penetrated, a capability that distinguishes it from competing devices. The low-cost ice sensor can be retrofitted to existing aircraft or embedded in new anti-ice and deicing systems.

Sensor blankets. IDI's ice sensor uses ultrasensitive capacitance electronics to measure small amounts of ice buildup on aircraft surfaces. Blankets of thin-film sensors placed along the surface of the wing detect small changes in the dielectric constants of air, ice, and water. Noting the differences in dielectric constants allows the sensor system not only to discern ice from water, but to track the ice from its onset to a critical thickness threshold.

"The two biggest advantages of the technology are its nonintrusiveness and its ability to cover large surfaces," says Joseph Gerardi, IDI's president. "It doesn't stick out and vibrate in the wind like older probe technology. And it can be made in sheets to cover the entire wing." Mr. Gerardi indicated that BMDO- and NASA-funded SBIR contracts played a major role in advancing IDI's capacitance sensor technology. BMDO's interests lie in using the technology as part of a structural health monitoring system for satellites.

Smart deice. IDI's ice sensor is being incorporated into several "smart" products for detecting ice on aircraft, highways, and refrigeration systems. For example, through a licensing agreement with IDI, the sensor technology was transferred to BF Goodrich Aerospace (Uniontown, OH), a manufacturer of pneumatic deicing systems for business and commercial aircraft. In another example, IDI is working with the Department of Transportation to refine the sensor for use in detecting icy road conditions on smart highways. In addition, the company recently met with a major appliance manufacturer that is interested in using the sensor technology in consumer freezers.

IDI has developed a complete deicing package for small aircraft, called the Impulsive Deicing System (IDS), which uses the ice sensor to automatically activate a deicing system. The IDS is currently being evaluated by several aircraft manufacturers, including Boeing and Bell Helicopter, for possible integration into future jet aircraft. Prototype systems have been delivered to Cessna and Raytheon Aircraft for evaluation, and the system has successfully completed flight testing in airborne icing conditions. Raytheon is in the process of FAA-certifying the IDS for use on its Premier series of business jets. IDI is working with Cox and Company to manufacture components of the deicing system.

■ For more information, contact Gail Hickman via telephone at (607) 257-0533 or via E-mail at idi@innodyn.com. You can also visit IDI's Web site at <http://www.lightlink.com/idi>.



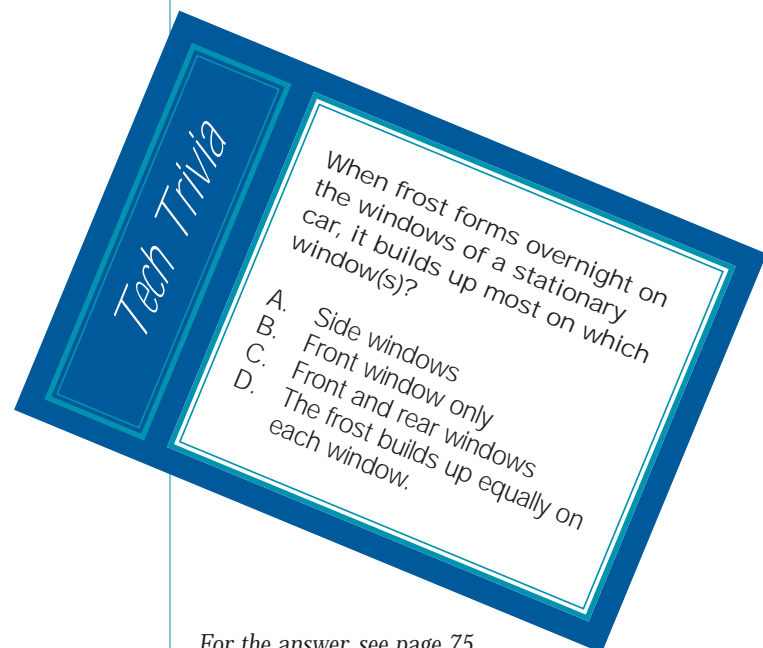
What Does It Mean to You?

Ice sensors will help pilots keep airplane wings free from ice in flight, making air travel safer over mountainous areas, the Great Lakes, and Alaska where icing is most likely to occur.



What Does It Mean to Our Nation?

Pilots of commuter aircraft could avoid fatal crashes and accidents by relying on ice sensors, instead of visual clues, to detect signs of hazardous ice.



For the answer, see page 75.

TECH TRIVIA ANSWERS



Introduction

■ Page 7 The answer is D.

The six conflicts include Egypt/Syria–Israel (1973); Iran–Iraq (1980 to 1988); United States–Libya (1986); Afghanistan–Afghan Rebels (1988 to 1991); United States/Saudi Arabia–Iraq (1991); and North Yemen–South Yemen (1994).

Communications and Networking Technologies

■ Page 15 The answer is A.

COWs stands for cell on wheels. (Source: CNN Interactive)

■ Page 17 The answer is A.

In Bell's honor, all phones served by the Bell System in the United States and Canada went silent for one minute. (Source: Sprint)

■ Page 19 The answer is B.

Infrared lasers are much more useful for imaging tissue than for ablating or altering it. In general, lasers used in eye surgery have shorter wavelengths than those in the infrared region. (Source: National Technology Transfer Center—Washington Operations)

■ Page 21 The answer is B.

Web sites containing new images transmitted from the Mars spacecraft received some 100 million hits in five days—a world record, according to NASA. (Source: Science News Online)

Energy Technologies

■ Page 25 The answer is B.

Bottled water originating from well-protected underground sources (wells or springs) that are not subject to intermittent contamination from surface water, and that have been consistently shown to be free of coliform bacteria, will be safe to drink. However, the deadly microbe *Cryptosporidium* has been found in swimming pool water, surface waters, and food. (Source: Centers for Disease Control and Prevention)

■ **Page 27** **The answer is C.**

The speed of light is 186,282 miles per second. Therefore, sunlight takes 8.3 minutes to travel the 93 million miles to Earth. If a cheetah were to travel that same distance at its top speed, the world's fastest land animal would reach Earth in about 151 years! (Source: *University of Michigan*)

■ **Page 29** **The answer is B.**

In 1941, Packard began offering air conditioning in several models, and Hupmobile, Graham-Paige, and American Bantam ceased automobile production. (Source: *Motorcraft*)

■ **Page 31** **The answer is C.**

The human brain probably has enough electricity to light a 15- or 20-watt bulb, like the one used in your refrigerator. This electricity helps your ideas jump around from cell to cell. Now you can really say you have a “bright idea”! (Source: *Commonwealth Edison Company's Electric Universe*)

Health and Medical Technologies

■ **Page 35** **The answer is C.**

Over 80 percent of biopsied breast abnormalities are benign, but any breast lump must be evaluated by a physician. With new, less invasive biopsy procedures, this examination can sometimes take place in the physician's office. (Source: *National Alliance of Breast Cancer Organizations*)

■ **Page 37** **The answer is D.**

In addition to vertebral fractures, osteoporosis annually causes 300,000 hip fractures, 200,000 broken wrists, and 300,000 fractures of other bones. An estimated 37,500 people die each year following fracture-related complications. (Source: *National Osteoporosis Foundation*)

■ **Page 39** **The answer is D.**

Beginning in 1907, Raman worked for 10 years in the Indian Finance Department while conducting his physics research and publishing more than 30 papers. In 1924, he was elected Fellow of the Royal Society, London, and was knighted by the British government in India in 1929. In 1930, he received the Nobel Prize in physics for the discovery of the Raman effect, thus becoming the first Asian to receive the award in science. (Source: *The Nobel Prize Internet Archive*)

■ **Page 41** **The answer is C.**

Seeing with electrons, scientists have unraveled the structure of matter and explored the mysteries of the universe. But no one has conclusively proved that the universe began sometime between 10 and 20 billion years ago in an event called the Big Bang. (Source: *Science Museum*)





Manufacturing Technologies

■ Page 45 The answer is D.

Although the luminous intensity was very low, the gallium arsenide–phosphorus LEDs still found use in a variety of applications, primarily as indicators. (Source: Marktech Optoelectronics)

■ Page 47 The answer is B.

Assembling a chassis every 1 1/2 hours, the company produced 308,162 cars in 1914, which was more than all other automakers combined. (Source: Ford Motor Company)

■ Page 49 The answer is C.

The number of transistors has significantly grown from 2,300 on the 4004 chip to 7.5 million on the Pentium II chip. (Source: Popular Science)

■ Page 51 The answer is A.

Conkers are the hard fruit of the horse chestnut tree. In Great Britain, school-children drill a hole in the conker and thread a string through it. One player dangles his/her conker by the string, while the opponent swings his/her conker on its string and attempts to strike the hanging conker. Players take turns doing this until one conker is so damaged that it is dislodged from its string. Naturally, the stronger and harder the conker, the more chance of success. (Source: New Scientist)

Materials Technologies

■ Page 55 The answer is B.

On the *Spirit of Akron*, the old sign required seven pieces of heavy equipment to be installed for each excursion. The new LED sign requires only one piece—a small, hand-carried laptop computer. (Source: Goodyear)

■ Page 57 The answer is C.

It takes water to either grow or make our foods. This water is either supplied by nature as precipitation or added by humans during the growing/production process. But it is difficult to tell by the size or texture of a food how much water was actually used to produce the food item. For example, single servings of lettuce, watermelon, and steak require 6, 100, and 2,607 gallons of water, respectively. (Source: U.S. Geological Survey)

■ Page 59 The answer is B.

Inside a computer disk drive, the spinning disk creates an air cushion over which the electromagnetic read/write head floats. Depending on design, this air buffer ranges from 2 to 15 microns. Red blood cells average about 10 microns in thickness. By contrast, the thickness of a smoke particle and fingerprint is about 30 microns. A human hair is about 75 microns thick. (Source: Data Recovery Laboratories, Sandia National Laboratories)

■ **Page 61** **The answer is C.**

Technically speaking, the “W” stands for winter grade. 10W-30 means that the oil will flow like a normal 10 weight oil at a low (winter) temperature, but will flow like a 30 weight oil at normal temperatures. (Source: *Indy Lube Express, Sloan Tech Tips*)

Optical and Sensor Technologies

■ **Page 65** **The answer is D.**

The price of single first-class passage aboard the *Titanic* in today's dollars would be roughly \$50,000. (Source: *St. Petersburg Times*)

■ **Page 67** **The answer is D.**

For many years, scientists used the Bertillon System, which recorded the dimensions of certain skeletal body parts. But in 1903, Leavenworth Federal Penitentiary received a prisoner named Will West. Shockingly, Will had almost the same Bertillon measurements (as well as appearance) as another prisoner. Even though the two unrelated criminals looked identical and had similar names, their fingerprints were, of course, different. Thanks to this remarkable case, fingerprinting became the standard for personal identification. (Source: *Federal Bureau of Investigation*)

■ **Page 69** **The answer is A.**

In the 1870s, bicyclists, known then as “wheelmen,” were challenged by rutted roads of gravel and dirt. They united in 1880 as the League of American Wheelmen to lobby the government for more paved roads. Today, known as the League of American Bicyclists, this organization still works to improve the quality of bicycling in America. (Source: *League of American Bicyclists*)

■ **Page 71** **The answer is C.**

Vertical door windows receive the bulk of their heat radiation from the ground, trees, and buildings around them. Sloping front and back windows receive most of their heat radiation from the sky, which is much colder. The result is that front and back windows cool down much more rapidly than the door windows, and the ice precipitated from the air in contact with these windows builds up more quickly. (Source: *New Scientist*)



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V W X Y Z



WHAT'S IN A NAME?



If an inventor wanted to create a company to sell his or her latest innovation, what should the inventor call it? Names are very important to small businesses. They form the image and identity that the customers see and understand. Below are four uniquely named companies commercializing technology funded by the Ballistic Missile Defense Organization. A brief explanation of how each got its name is also provided.

1. ***Autonomous Technologies Corporation***, a developer of next-generation excimer laser instruments for laser vision correction. Autonomous was named after the company's first military contract, which was called the Autonomous Terminal Homing Program. "Under this program, we investigated the use of 3-D imaging laser radar [ladar] to guide cruise missiles," says Randy Frey, chief executive officer and president of Autonomous. "Later, while incorporating ladar technology to autonomous surgical systems, we realized the name still applied. So we kept it."

2. ***EMCORE Corporation***, a developer of integrated compound semiconductor solutions. Rick Stahl, one of EMCORE's founders, says the company's name had to emphasize its strategic focus in the core of electronic materials. By combining the "e" in electronic, "m" in materials, and the word "core," a new, unique company name was created.

3. ***Sagebrush Technology, Inc.***, a manufacturer of precision positioning devices. Sagebrush was given its name to help customers identify with the company's location—Albuquerque, New Mexico. "I like living in Albuquerque and I saw how much everyone enjoyed visiting here," says Don Carson, the founder of Sagebrush. "I thought by naming the company Sagebrush Technology, people would remember us more, especially when they think of images of the rugged Southwest."

4. ***Theseus Logic, Inc.***, a developer of clockless designs for microprocessors. Ken Wagner, president of Theseus, speaks of the young hero Theseus who killed the evil Procrustes, a legendary robber in Greece. "Procrustes forced travelers onto his bed where he stretched or mutilated them," says Wagner. "Today, the word 'Procrustean' means any standard to which precise conformity is forced. So we named the company Theseus because we are, in effect, slaying the proverbial procrustean microprocessor design with our clockless technology."